Industrial QUALITY CONTROL

VOL. V MAY, 1949 NO. 6

CONVENTION ISSUE

THE SHEWHART MEDAL

(See pages 25-26)

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For further information write to Professor C. C. Craig, 3534 Rackham Building, University of Michigan, Ann Arbor, Michigan.

Industrial Quality Control

VOL. V **MAY, 1949** **No. 6**

Table of Contents

	Page
Quality Control for the Chemical Industries	3
Advanced Course in SQC—Purdue University	3
Michigan Quality Control Course	3
The Advancing Frontier of Quality Control Colonel Leslie E. Simon	5
Quality is a Business Must J. P. Spang, Jr.	9
Operating Characteristics of Average and Range Charts Henry Scheffe	13
The Place of the American Society in Modern Quality Control Wade R. Weaver	18
The Case of the Perjured Control Chart V. E. McCoun	20
Report of the Third Annual Convention, ASQC, and the Third Annual New England Quality Control Conference	23
Book Review	26
American Society News	
George D. Edwards Elected Honorary Member	29
Board of Directors Meeting Held	29
Brumbaugh Award Committee	30
Plans for the Brumbaugh Award	30
New Sections Recognized	30
Annual Meeting 1949	30
Yearbook 1948-49	30
Members-In-Training	30
Executive Committee Meets	31
Notice	31
Classified Advertisements	
Consulting Services	31
Positions Wanted	31
Advance Notice—Fourth Midwest Conference	31

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The Advancing Frontier of Quality Control*

COLONEL LESLIE E. SIMON

ORDNANCE DEPARTMENT

DIRECTOR, THE BALLISTIC RESEARCH LABORATORIES, ABERDEEN PROVING GROUND, MARYLAND

THE EXPANSION OF QUALITY CONTROL

The past two and one-half decades have seen "quality control" become progressively an important adjunct to four engineering or industrial fields; (1) Manufacturing process, (2) Acceptance inspection, (3) Study of systems or processes (largely industrial management), and (4) Research and development. I put quality control in quotation marks because the scope of activities associated with the term has now extended far beyond original concepts associated with it. Nevertheless, there are scarcely any of the many benefits that have come from quality control and its allied techniques that were not anticipated in Walter A. Shewhart's two books, one of which was published in 1931 [1] and the other in 1939 [2]. The quarter-century mark seems a fitting time to note the progress of quality control, to attempt to distinguish between quality control in its original form and the field of industrial statistical methods now associated with the term, to make some estimate of how statistical methods affect us as engineers, and finally to get some idea of how it assists us in contributing to the science of engineering.

PRE-WORLD WAR II QUALITY CONTROL

In this discussion, I shall use quality control in its original sense, i. e., statistical control of product during the process of manufacture. According to Dr. Shewhart, quality control was born in 1924. During the late 1920's a number of important papers by Shewhart and others appeared in the Bell System Technical Journal, but Shewhart's work did not attract serious attention until he was invited to give a series of lectures at University College, Cambridge, England in 1932. Its cordial reception and utilization in England contributed much to its first real stimulus in the land of its origin.

COLONEL LESLIE E. SIMON

In the 1930's quality control advanced steadily but relatively slowly. Outside the Bell System, it was used to a limited extent in a considerable number of the larger corporations, taught (or taught along with other statistical methods) in a few academic institutions, used to a limited extent by the Army Ordnance Department, and sponsored by the American Society for Testing Materials [3]. Not until 1940 was the American Standards Association Committee on Quality Control organized, and its War Standards Z1.1, Z1.2 and Z1.3 were published [4] in 1941 and early 1942. Quality control's growth curve may have been exponential, but the exponent was only slightly greater than unity.

This era was characterized by very strong emphasis on the engineering practicality of quality control. Essentially, quality control consisted of: (1) selection of the sample, (2) inspection of the sample, (3) statistical treatment of the inspection results, and (4) identification and elimination of assignable causes of undue variability. The superiority of the control chart over other possible competing methods is the statistical validity of its control limits in providing a sound basis for **action;** its effectiveness is dependent upon prompt and competent engineering action to locate and **remove** the causes of the bad quality that are signaled by the control limits. The 3-sigma limits were chosen because of their proved usefulness in practice and not on considerations of mathematical probability. Estimation, the analysis of variance, and calculated percentage probabilities were regarded rather as hazards to the acceptance of statistical methods in industrial work.

Meanwhile, even we who were advising caution, were finding it highly desirable not only to add variations to the control chart, but to add techniques to our stock which had little or nothing to do with process control. For example, the use of range instead of standard deviation for small samples began early and gained rapidly in popular use, the control chart for defects per arbitrary unit arose from some questions asked the Ballistic Research Laboratories by Frankford Arsenal about work where there was no apparent sample size; the concept of power curves or Probability of Acceptance Curves [6], [12] became popularly known as "O.C. Curves" [5] in connection with the discussion of acceptance criteria; control charts with asymmetric limits proved useful in grading stocks of war reserve ammunition (quality determination, not process control), etc. However, probably the most important single contribution was the publication in 1941 of the Dodge-Romig Sampling Tables [6] which made readily available some sampling plans which began in the Bell Laboratories in the late 1920's. The sampling tables gave a great stimulus to sampling inspection procedures. This latter application certainly

* Acceptance Address by the Society's first Shewhart Award Medalist. Presented at the Third Annual Convention Dinner, ASQC, Boston, May 5, 1949.

is not quality control (in the old sense); Dodge is author of the often quoted statement, "You cannot inspect quality into the product."

Finally, both quality control engineers who held executive positions and people who had observed the success of quality control began to ask for statistical analyses of complex data (much of this work is known today as Industrial Experimentation [7]) and for statistical aid in planning experiments so as to yield a maximum of information. Statistical methods (or quality control principles) were definitely entering into fields other than process control. A partial explanation for the very moderate pre-World War II penetration of quality control principles into new fields is given in Figure 1. The new fields require more quality control engineers, and more general reception of statistical technique. Quality control was barely established in its basic field of manufacturing process.

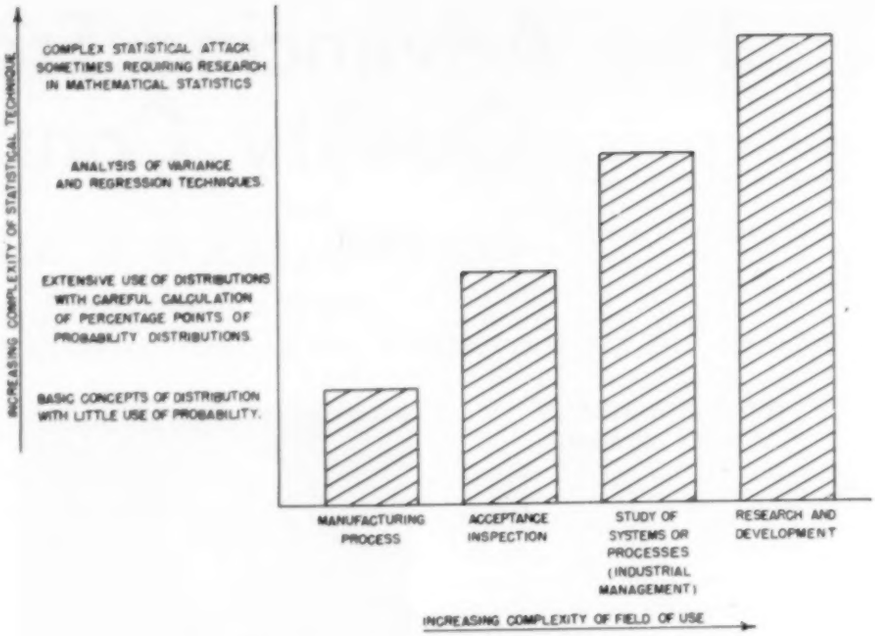
INCREASING COMPLEXITY OF STATISTICAL TECHNIQUE
COMPLEX STATISTICAL ATTACK SOMETIMES REQUIRING RESEARCH IN MATHEMATICAL STATISTICS
ANALYSIS OF VARIANCE AND REGRESSION TECHNIQUES
EXTENSIVE USE OF DISTRIBUTIONS WITH CAREFUL CALCULATION OF PERCENTAGE POINTS OF PROBABILITY DISTRIBUTIONS
BASIC CONCEPTS OF DISTRIBUTION WITH LITTLE USE OF PROBABILITY.
MANUFACTURING PROCESS
ACCEPTANCE INSPECTION
STUDY OF SYSTEMS OR PROCESSES (INDUSTRIAL MANAGEMENT)
RESEARCH AND DEVELOPMENT
INCREASING COMPLEXITY OF FIELD OF USE

FIGURE 1 — TECHNIQUE vs. FIELD OF USE

THE POPULARIZATION OF QUALITY CONTROL

World War II found quality control ready for use, but neither the general public was ready to accept it nor were there enough quality control engineers to administer it on a large scale. A variation of the Control Chart technique known as Analysis of Acceptance Tests and Inspections had greatly assisted the Ordnance Department in the early phases of the emergency, and consequently quality control was invited to the conference table when Ordnance plans were being finalized for the vast war emergency. Those who represented quality control recommended against its being given official status, and recommended instead that acceptance sampling techniques [8] be used to screen out bad quality. It was contemplated that frequent rejections suffered by producers of poor quality and infrequent rejections incurred by manufacturers who used quality control would be cogent inducements to the increased use of this statistical method which contributes so much to the economical manufacture of uniform munitions [9]. This program proved so effective that similar systems were soon adopted by the Navy [10], Quartermaster Corps, and Signal Corps. Almost concurrently, the demand of industry for people trained in quality control became so strong that upon the recommendation of a Committee of the National Research Council, the War Production Board sponsored the 8-day training course under the Engineering, Science and Management War Training (ESMWT) programs in the principal cities of the United States. Thus, executives and managers in many industrial firms learned of the practical advantages of quality control, and a large body of persons was created in a short length of time who had at least a rudimentary knowledge of quality control techniques.

POST WORLD WAR II QUALITY CONTROL

At the end of the war, the quality control engineers paused to consider their professional future. Profesisonal men are never static. They either forge ahead or drift backward. Quality control engineers needed an organization to further their professional education, promote the exchange of ideas, and keep them aware of current affairs that affect their professional activities. This need led to the organization of the American Society for Quality Control, which was formed from the nuclei of the many small local societies that resulted from the ESMWT programs. The trends in membership and particularly the character of articles in its journal, Industrial Quality Control, are evidence of the changing scope of quality control, of how the profession of quality control engineering affects us, and of how we affect the science of engineering. The background that I have just outlined will help us in interpreting the evidence.

CHANGING PROFESSIONAL TECHNIQUES

Let us first examine what changes are taking place in the basic tools of our profession and let us try to discover if the trend is in the right direction.

In 1941 the War Emergency Technical Committee questioned most seriously the inclusion of a table of probability limits, in addition to the table of 3-sigma limits in the ASA standards. The extension was adopted largely on grounds of giving the documents broadest appeal. The probability limits did no apparent harm, and surely aided in the dissemination of the work.

At the beginning of the War, many of us feared that emphasis on Acceptance Sampling techniques would result in their "selling too easily" and to people's falsely relying on "inspecting quality into the product." However, they did the country a great service, extended the general use of statistical methods in acceptance inspection, and encouraged the broader use of process quality control.

During the period when ASQC was being organized, there was widespread apprehension of the influence of theoretical people. Emphasis was laid on keeping the journal at the control chart level. Today the tone of Industrial Quality Control is somewhere about the mid-point of the ordinate of Figure 1. However, I am not at this point presenting an argument. I am only presenting evidence.

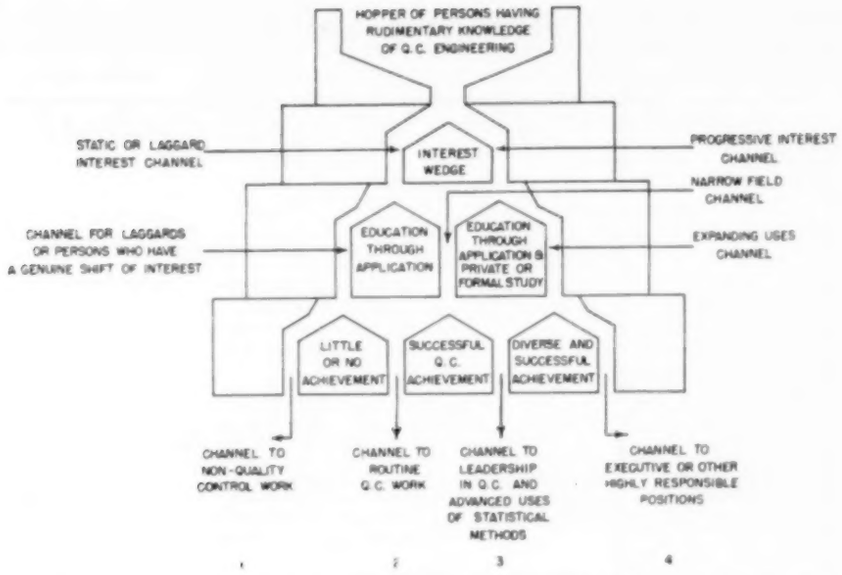
HOPPER OF PERSONS HAVING RUDIMENTARY KNOWLEDGE OF Q.C. ENGINEERING
STATIC OR LAGGARD INTEREST CHANNEL
INTEREST WEDGE
PROGRESSIVE INTEREST CHANNEL
NARROW FIELD CHANNEL
CHANNEL FOR LAGGARDS OR PERSONS WHO HAVE A GENUINE SHIFT OF INTEREST
EDUCATION THROUGH APPLICATION
EDUCATION THROUGH APPLICATION & PRIVATE OR FORMAL STUDY
EXPANDING USES CHANNEL
LITTLE OR NO ACHIEVEMENT
SUCCESSFUL Q.C. ACHIEVEMENT
DIVERSE AND SUCCESSFUL ACHIEVEMENT
CHANNEL TO NON-QUALITY CONTROL WORK
CHANNEL TO ROUTINE Q.C. WORK
CHANNEL TO LEADERSHIP IN Q.C. AND ADVANCED USES OF STATISTICAL METHODS
CHANNEL TO EXECUTIVE OR OTHER HIGHLY RESPONSIBLE POSITIONS
1
2
3
4

FIGURE 2 — SCHEMATIC DISTRIBUTION OF PERSONNEL ENTERING THE FIELD OF MODERN QUALITY CONTROL

CHANGING PERSONNEL

The evidence of changing techniques must be examined in the light of changes in people. There is less concrete evidence in this field and the presentation must, of necessity, be more subjective. By way of analogy, I would like to compare the persons in our quality control professoin with a model of a binomial machine (See Figure 2).

At the end of World War II, we had a large number of people who had at least a rudimentary knowledge of quality control. Many are still entering the field, and I shall have more to say about this later. We may regard them as entering the binomial hopper. The first "wedge" they encounter is the interest wedge. A decision at this point as to whether or not to go on with self-education in statistical methods is a matter of paramount importance. Loss of interest (and interest generally means learning more advanced techniques) is probable loss of a leader, even probable total loss of an individual to quality control. We might note in passing that the position of the interest wedge is largely influenced by the agency that imparts the rudimentary education and by members of ASQC.

The next diversion points which affect the careers of our people are the education wedges. The channels which result from these wedges are obvious from Figure 2. The position of the left hand education wedge is determined largely by supervisors and company policy; that of the right hand wedge by our journal, clinics, section meetings, and other ASQC activities as well as by individual initiative.

The positions of the achievement wedges are largely dependent upon the individuals, but are nevertheless influenced by favorable publicity given to quality control, the prestige of our organization, and recognition of the contributions of statistical methods to engineering.

The "tails" of the final distribution are important. All persons channelled to non-quality control work are not only lost, but in self defense are likely to be detractors from quality control engineering. Those channelled to executive or other highly responsible positions are not lost to quality control. Whereas they probably become too busy to do much quality control work themselves, their achievement of high position is probably due at least in part to quality control, they maintain an interest in it and foster it, and they become the big consumers of quality control information.

Of course it is not proposed that the distribution of quality control engineers is $(0.5+0.5)^n$ or even that it is truly binomial. However, the mere framework of the illustration shows that confinement of our activities to the original concept of quality control would not only withhold recognition from the important right hand part of the distribution, but would in all probability result in the decadence of the whole profession, and withdrawal of one of the strongest stimuli to the advancement of engineering.

THE SPIRIT OF SCIENTIFIC INQUIRY

One of the strongest influences that have promoted both the success and the advancement of quality control is an attitude of scientific inquiry on the part of the persons engaged in it. At no time has anyone been willing to regard quality control as a finished thesis. No one, from Dr. Shewhart on down has shown a willingness to dignify himself as any kind of ultimate authority. Rather, all have regarded themselves as students not only willing to ask questions, but able and willing to learn from each other. Thus quality control has not only proved inviting to engineering minds at industrial institutions, but was constantly associated with academic institutions long before such association had achieved its present-day popularity with industry and laboratories.

There is no more powerful stimulus to new things than the free exchange of ideas between workers. I have been asked if the Bell Laboratories were not very generous in freely disclosing their initial discoveries in quality control? I would say perhaps so, but it is not important; it is much more important to give those laboratories credit for using good sense. The biblical injunction, "Cast thy bread upon the waters: for thou shall find it after many days," applies to ideas perhaps even more cogently than to material things. Important as the Bell Laboratories' contributions have been, they have almost certainly received far more in return than they have given. The exchange of ideas is a mathematical anomaly in that all concerned can receive back more than they give. The firm that employs a quality control engineer should realize (a) that the man that it employs should be sufficiently competent to contribute something in response to scientific inquiry; not be just a receiver; (b) that he must be free to discuss his work with colleagues, and (c) that his attendance at technical meetings must be encouraged and financially supported [11]. The firm that fails to recognize these things is not likely to get a good quality control engineer, and even if one could be acquired, he would be gravely handicapped in this relatively new and expanding field.

SOMETHING OF THE FUTURE OF QUALITY CONTROL

If one will concede that quality control is changing, we may well ask if the changing process is in its early or late stages and will it be for better or for worse? Again, in the light of history, I believe we can make a qualitative prediction, and we are in a fortunate position in which an error of even three or four will not change the quality of the prediction. Figure 3 charts the four fields of industrial statistical activity against known bases of attacking problems. Certainly no claim for accuracy can be made for the distribution curves that I have drawn opposite each field of use in Figure 3; but, for the purpose of looking to the future, only the right hand "tails" of the curves are important. We are almost certain that the penetration of statistical methods is greatest in the bottom field (Manufacturing Process) and that it falls off to a least value in the top field (Research and Development). Furthermore, we can be perfectly sure that quality control has not reached even half its growth even in its major field (Manufacturing). Thus, quality control engineering is in its early youth, and a great future lies ahead of it.

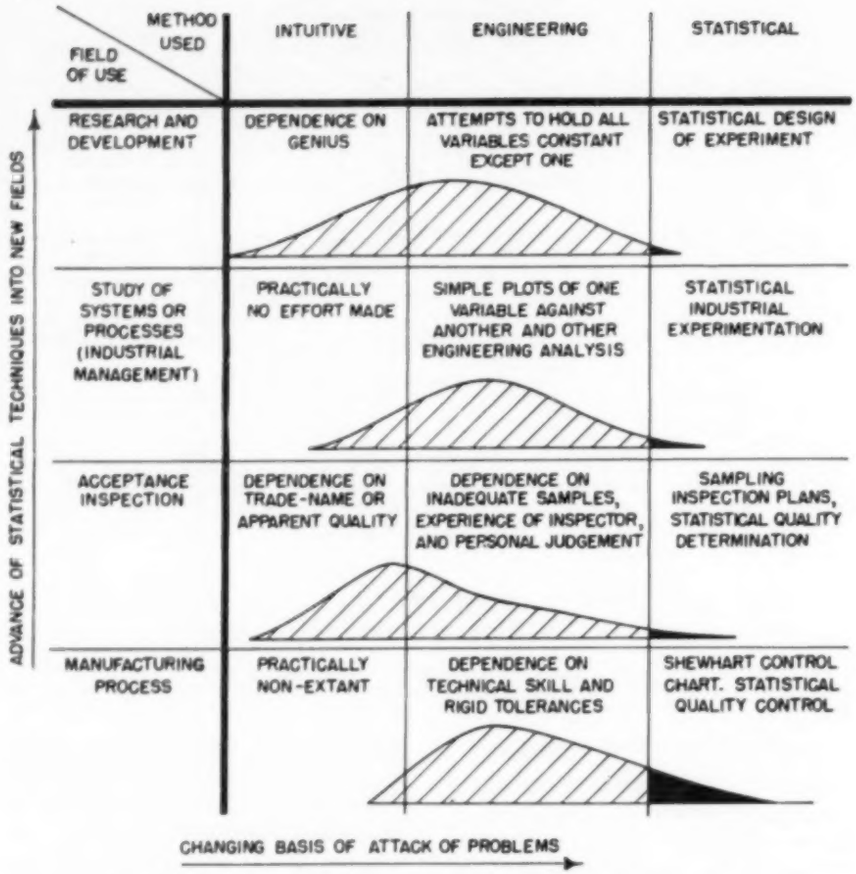
METHOD USED
FIELD OF USE
INTUITIVE
ENGINEERING
STATISTICAL
RESEARCH AND DEVELOPMENT
DEPENDENCE ON GENIUS
ATTEMPTS TO HOLD ALL VARIABLES CONSTANT EXCEPT ONE
STATISTICAL DESIGN OF EXPERIMENT
STUDY OF SYSTEMS OR PROCESSES (INDUSTRIAL MANAGEMENT)
PRACTICALLY NO EFFORT MADE
SIMPLE PLOTS OF ONE VARIABLE AGAINST ANOTHER AND OTHER ENGINEERING ANALYSIS
STATISTICAL INDUSTRIAL EXPERIMENTATION
ACCEPTANCE INSPECTION
DEPENDENCE ON TRADE-NAME OR APPARENT QUALITY
DEPENDENCE ON INADEQUATE SAMPLES, EXPERIENCE OF INSPECTOR, AND PERSONAL JUDGEMENT
SAMPLING INSPECTION PLANS, STATISTICAL QUALITY DETERMINATION
MANUFACTURING PROCESS
PRACTICALLY NON-EXTANT
DEPENDENCE ON TECHNICAL SKILL AND RIGID TOLERANCES
SHEWHART CONTROL CHART. STATISTICAL QUALITY CONTROL
ADVANCE OF STATISTICAL TECHNIQUES INTO NEW FIELDS
CHANGING BASIS OF ATTACK OF PROBLEMS

FIGURE 3 — CLASSIFICATION OF CONTROL TECHNIQUES— FIELD OF USE vs. METHODS USED

SOME TENTATIVE CONCLUSIONS

1. In only a quarter century quality control has changed so much that the term has lost some of its descriptive values. Nevertheless, it is still sufficiently valid for there to be no temptation to change the name to a broader and perhaps no more descriptive name, such as Industrial Statistical Methods, any more than there should be a wish to exchange the sigma on the control chart shield of our society for an R. We should merely understand what we mean by the name.

2. We should not resist the advancing frontier of quality control but encourage advancement by fostering the spirit of scientific inquiry and through such media as formal education, educational meetings, and other exchanges of ideas. However, the policy of insistence on sound engineering along with every statistical attack should be unrelentingly continued. Whereas the power of the technique inheres in the statistical concept, the marked success of its application and its consequent rapid growth in use is attributable to the engineering acumen of the people who apply it. It is the duty of ASQC to hold the balance here.

3. Quality Control so contributes to the success of the engineer as to promote many quality control engineers out of the field of application to more responsible positions.

4. Quality Control contributes to the science of engineering not only by enabling the engineer to do what he wants more swiftly, effectively, and assuredly; but by promoting whole systems and processes from a traditional, intuitive or engineering rule-of-thumb basis to a firm and efficient scientific basis.

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Quality Is a Business Must*

J. P. SPANG, JR.

PRESIDENT, GILLETTE SAFETY RAZOR COMPANY

INTRODUCTION

The American Society for Quality Control, as a formal organization, is three years old. In essence, you are centuries old. You know, as I do, that the reason for the existence of your Society preceded its birth by hundreds of years. Quality, and the control of it, have always been two of the fundamental concerns of industry. Even before the industrial revolution, craft guilds rose and fell on the quality of their workmanship. The successful manufacturer, throughout the years must have constantly strived for quality by the very reason of his continued existence. Therefore, quality and its maintenance are as old as manufacturing itself.

I make these observations as a sort of preamble to my remarks tonight. Their purpose is to indicate to you that management, though perhaps not technically trained in the subject matter of your science, is, and always has been deeply concerned with the problems you are helping to solve. The chairman of your convention, Mr. W. R. Purcell, has made this point most eloquently in one of his papers. He has stated that "as a broad function, quality control is an essential element of good manufacturing management, and any industrial organization which is competing successfully today must have had quality control in a fairly successful form since it was founded, otherwise it could not compete successfully."

I particularly like Mr. Purcell's reference to the necessary part Quality Control must have played from the beginnings of any successful organization for it to have maintained its leadership throughout the years in this competitive free enterprise system under which we live and work.

MR. JOSEPH P. SPANG, JR.

QUALITY CONTROL AT GILLETTE

Without equivocation, I can state that management at Gillette is vitally interested in Quality Control. We have every reason to be. For nearly fifty years now, we have made a quality product. To the limit of our abilities and our resources, we are going to continue to make quality products.

Quality Control within the present day definition had its beginnings at Gillette in the fall of 1946. It was then that a department and staff, assisted by Dr. Joseph M. Juran, were set up to institute quality control methods in our manufacturing processes. Our experience record since then is the reason I can so frankly state our firm belief and deep interest in the methods you people have evolved. Our experiences in these past three years have enabled us to evaluate in dollars and cents the benefits we have derived. I should like to take just a few moments to cite some of these experiences.

In our razor division, savings effected by the institution of quality control have been considerable. Those methods were instituted in this division in the first quarter of 1947. By the middle of 1948, our costs from spoilage, rework and inspection were cut by 76 percent. Translated into dollars, that 76 percent became a figure that I can assure you was most impressive.

In this connection, I should like to digress for just a moment. What counts most with management is results. To become accomplishments, results must be understood and appreciated by all levels of management. Management wants brief, non-technical, and periodic reports, and in those reports keep the emphasis on the dollar results.

In effecting the savings I just referred to, the experience of one department in our razor division is strikingly illustrative. The operation in this department is the soldering of a small metal cap over the legs of what we call the "spider" of our one-piece razor. The "spider" is that bar down the middle of our razor which positions the blade. This soldering is a simple operation, yet it does require a definite degree of skill. Rejections for minor defects in

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this step were consistently running at a 25 percent rate. This was a real headache to come from a simple enough operation.

The problem was studied from both quality control and a methods point of view. Not to give you fellows all the credit, I will say that after this study, there was an improvement in methods. But to quality control must go the major share of the improvement made. A system of inspection was devised which in addition to eliminating 100 percent inspection, gave the operators a definite incentive towards perfection in their work. Within a short time after the institution of the improved methods, and the quality control system of inspection, rejects dropped from 25 percent to 2 percent. Today, and for the past several months, the reject rate in that department has been consistently less than one percent.

The boost in the morale of employees which comes with the installation of quality control methods has an importance never to be overlooked. I was very happy to see this point stressed in an article in the New York Times a few Sundays ago. Mr. C. W. Kennedy, another official of this convention, stressed in that interview that "a further benefit of adequate quality control is improved employee morale." Mr. Kennedy said that 90 percent of employees engaged in production want to do their work the right way, and subconsciously resent doing it any way which causes rejections. He cited examples in which machine operators make out their own quality control charts, at the same time demonstrating great pride in the record of their accepted output.

In addition to these concrete evidences of the effectiveness of quality control, management, I sincerely believe, feels that quality control makes the manufacturing road a much safer one on which to travel. Quality control gives us the directional signs. It becomes a road map. The road itself is no different, but with the aid of these signs, the driver is guided so that he avoids wrong turns, accidents, and gets to his destination more safely, more quickly, and more efficiently.

QUALITY CONTROL ESSENTIAL IN ALL PHASES OF SUCCESSFUL MANAGEMENT

In any talk on quality, or quality control, it must be remembered that the turning out of a quality product is not governed entirely by gauges, micrometers, photo-electric cells, control charts, or three-sigma limits. No, a quality product is not the result of the manufacturing process alone. In this I am sure you will agree with me. I am sure you will agree that a fine candy could not be turned out, even with quality control, under unsanitary working conditions. An intricate mechanism—a watch for example, could not be assembled in a poorly lighted factory. Quality must be evident in every phase of a successful business today from the first workings of the raw material right down to the time the end product is placed in the consumer's hands. That means in your factory, your personnel, your market research, your sales methods and your advertising.

The plant, or factory, in which a product is manufactured must be well lighted, well ventilated. Colors used in the interior of a factory can do much toward making working conditions more pleasant for your employees. Adequate and easy access from one part of a plant to another is a factor to be considered. An adequate recreational program is by no means removed from the essentials which go into the manufacture of a quality product.

Of even greater importance, you will agree, than the working conditions themselves is the quality of the personnel for which you provide those working conditions. In the selection of this personnel the greatest judgment should be exercised. I do not mean that exercise of this careful judgment should apply only to top personnel or to foremen or to supervisors. The right person for the right job is important no matter how small a part that person's contribution may play against the total. We here in New England, of course, may have been spoiled in the matter of fine workmen and fine workmanship. We have for long been noted for our skilled labor force. This has been a decidedly contributing factor to the reputation of high quality products turned out by this section of the country.

I would say then that the first two essentials in the manufacture of a quality product are (1) the quality conditions in the plant where the product is manufactured, and (2) the quality of the personnel which turns out the product. These are the tangible factors which go into the manufacture of a quality product. Never lose sight, though, of the intangibles. Market research is one; advertising is another; sales methods a third.

No matter how fine a product you may turn out, the day has long passed when the public will beat a path to your factory to purchase it. Modern marketing methods must be employed to move that product from the factory to the consumer. In these modern methods market research has become of primary importance. Marketing research is no longer limited to the designation of markets by income group, by population, by types of consumer. It goes much further these days. Marketing research is a method of testing a product. A manufacturer may well turn out what he considers a quality product. This product may be termed a quality one by all standards that research laboratories and technicians can devise, and yet the consumer will have none of it. Here's where marketing research comes in. Once this product has been turned out with all the refinements the engineers and technicians can devise, it must first be tested for consumer acceptance or lack of acceptance.

This is what we do at Gillette. Before we even consider national distribution of a new product, or of an improved product, we prove in this product by testing it in selected areas throughout the United States. We make a regular distribution of this improved product in, say, two of the six test cities we maintain. Then we check its consumer acceptance by way of sales against the sales in two other of our test cities where we have not as yet introduced this new item. We check the reaction of the retailers who are handling our new product. We make door-to-door checks of consumers who have purchased this new product. We ask them if they like it better than the old product. We ask them why they like it better. If contrarywise, they are not satisfied with the product, we find out why. We find out the reasons from the very source which is our ultimate aim —the consumer. This is the application of quality control techniques to marketing.

We in Gillette have long been firm believers in testing. We like to know not only the consumer's opinion of our products but his opinion of the products of our competitors and, believe me, we do get this information. Further, we act upon it.

This testing is not limited to the product itself. We also pretest all our advertising. Before final decision is made on any proposed advertising campaign, the ads in that campaign are tried out

in our test towns. The campaign is tested not only by the insertion of our visual advertising in local newspapers, but we also test our radio and television advertising. We cut our test cities out of the national network commercials, and have local announcers cut in the new commercials we are testing. We will do this in say three of our test cities and not do it in the other three. Thus we set up a definite control for this test by seeing what effects on sales the proposed campaign has as against the sales resulting from the current campaign.

In my mind, pre-testing and market research really pay off. They minimize the chance of self-deception. That is, you are far less likely to find yourself stuck with a product that is professionally perfect, but which fails to sell because it does not stimulate the nerves that run from your customers' minds to their pocketbooks.

Thus we see that right down the line quality is of utmost importance. On today's business scene quality in working conditions, quality in personnel, quality of marketing research and selling, and quality of advertising all must be there to round out the manufacturer's making and marketing of a quality product.

THE BUYER KNOWS QUALITY

As a manufacturer I firmly believe that quality of product is more important today than it has ever been. It has become increasingly important as we get deeper and deeper into a buyer's market. No longer are the substitutes of the war years and the conversion years satisfactory to today's consumer. Today when a consumer spends a dollar he or she wants to make certain of a dollar's value. We all recall the rapid rise during the war years of what is called "off-brand" merchandise. We smoked off-brand cigarettes. We used retread tires. We wore just about any kind of shirt our money would buy with little or no thought to its quality. In the razor blade business there were literally hundreds upon hundreds of brands of blades which came on the market during those years. They were rushed to the market, with little or no thought to quality, at a time when the majority of our blades and other recognized brands were going to the men in the armed services.

We have seen, too, the equally rapid disappearance of this off-brand merchandise. When nationally advertised products of known and long accepted quality came back on the market, there was a rush on the part of the public to buy them. The public knew that the quality of these products was there. The intervening war years did not erase from the public its memory of the inherent values in products made by manufacturers who stressed quality.

SOME ENCOURAGING ECONOMIC FACTS

This public rush to buy, which made 1948 the record year in our nation's history, has slowed down a bit. I am sure that you are all aware of this. You have all seen evidence of this dip on the financial pages of the papers you read. First quarter 1949 earnings have dropped, but I by no means go along with those who are predicting dire things for our economic future. It is my feeling that the period we are now in is one of price readjustment. The downward trend in prices simply indicates that man-made laws or government edict cannot prevail against the laws of nature, specifically against the law of supply and demand which is now reasserting itself as supplies come into balance with demand. It may be too optimistic to feel that we can have as good a year in 1949 as we had in 1948, but certainly there are no real reasons for us to feel that we are going to have a bad year. There have been no abnormal changes in our economy thus far which could bring about such conditions.

Let us take just a moment or two to check up on some significant statistics governing our economy today. First, a recent report by the National Association of Mutual Savings Banks shows actual savings to be eighteen billion dollars. That is a lot of money. That is a lot of money in the hands of our consuming public. It represents real purchasing power. This Association further stated that savings in the first quarter of this year had increased by 290 million dollars over the last quarter of 1948, and the total savings represent a 17% increase over the same period a year ago.

Contrast that eighteen billion dollars in savings with the personal savings in 1939 and 1940, the two years generally used these days as base points. In 1939 personal savings were two billion, seven hundred million. In 1940 they had risen to three billion, seven hundred million. I do not mean to infer that we are to consider 1939 and 1940 as normal years. I cite figures for those years for the principle reason of showing you how greatly our economy has expanded in the past ten years. Employment is still at a high figure. The most recent reports of the Bureau of Census show that in March of this year the gainfully employed numbered 57,644,000. That is ten million more employed than were at work in 1940 and thirteen million more than were working in 1939.

Our gross national income in 1939 was 72½ billion dollars. The fourth quarter of 1948 showed gross national income at the rate of 232 billion dollars.

Just one more figure and we will put statistics aside, but I do want to stress this figure because it is an important one. In 1939 personal income was 72 billion 600 million dollars. In February of this year personal income was at an annual rate of 217 billion dollars—three times as great as it was in 1939.

Figures such as these, I feel, should certainly put to rest this dire talk that we are hearing in so many places these days. Our entire economy has expanded greatly. In the past ten years we have had an amazing population increase. Since the last census in 1940 the population of this nation has increased by 17 million persons, a 13 percent increase in nine years.

The figures I have just recited are indicators of a strong and healthy economy. They are indicators of an economy which can be expanded still further. To bring about this expansion however, and to continue our present prosperity is going to be a job at which all of us will have to work hard. None of us can sit back and be complacent about the direction in which we are going. I think that each and every one of us has a very definite job at hand to see that our government—local, state and national—allows us a better climate in which to do business. This is not a job for the other fellow; this is a job for **you** and **me.**

FOREIGN RECOGNITION OF AMERICAN-MADE QUALITY

The figures and conditions I have just spoken about pertain solely to the domestic scene. There still exists on top of this a world hungry for the quality products that have made this nation foremost among nations. The economic outlook in Europe is definitely better today than it has been for many years. Marshal Plan aid is nearing completion of its first full year. Improvement in Europe's economy will most certainly be reflected over the long pull in an increased demand for American-made products. As those nations complete the first step in their recovery programs,

there may quite likely be a drop in exports of some of the products we have been supplying. But I feel that this will be for only a short time. I feel, too, that whatever slack may develop in our exports can be taken up by stockpiling in this country, and by our proposed armament program.

For the long pull, economic improvement in other countries throughout the world must result in higher living standards. As the living standards of those peoples improve, the markets for American-made, quality products will expand tremendously. An opportunity exists in foreign countries today for quality control methods and quality control personnel. American manufacturers are becoming increasingly aware of this. They are responding to this condition by building plants in foreign countries.

We at Gillette are doing just that ourselves. Within the next month we will add to the seven foreign factories we now have in operation, a new one in Mexico City. We expect to be in production there very shortly. In the past few years we have also expanded our operation in other foreign countries. We recently opened a new plant in Switzerland. We have doubled the capacity of our factories in Brazil and the Argentine. In England and France production of Gillette products has been greatly stepped up. And in all these expanded, or new activities, quality control techniques are playing their important roles.

You would be amazed and pleased, of course, as I was on my trip to Europe last summer at the automatic respect foreign consumers pay to products made either in America or by American methods. Just recently an officer of our company returned from three weeks in Latin American countries and he, too, was greatly impressed by the automatic endorsement given by the peoples of those countries to that good old label "Made in U.S.A."

In this country we stand in a certain amount of awe before imported products. The respect we pay, however, is as nothing compared to the respect paid to products imported from America. In Latin American and European countries when one speaks of "imported" he means an American-made product. It may be true that there does exist a fundamental smoldering of resentment against Americans by the peoples of many lands, but this resentment does not extend to the point where they don't want our goods.

I mentioned just a moment ago that Gillette was building a factory in Mexico City. You can be assured that even as the machinery is being installed, controls are being set up to insure the quality of the products which we will manufacture there.

Let me illustrate even further the tremendous respect paid American-made products by persons living in foreign lands. We know that once our Mexico City plant is in operation, we will have a drop in sales of our products there for a period of time. Why is this? It is because the blades and the razors we turn out in Mexico City will no longer bear the label "Made in U.S.A." At first the Mexicano will not believe that our products made in his own country can be as good as those made here in Boston.

They will be, of course. We will institute the same quality control methods in our Mexico City plant that we use in Boston, and in our other plants throughout the world. Each month samples of blades made in our foreign plants are received in Boston for comparative inspection with those made here. By the same token, blades made each month in our Boston factory are sent to our foreign plants for comparative inspection. The slightest deviation in uniformity is a matter for immediate corrective measures.

The reason that we are anticipating a drop in sales for a short time after the opening of our Mexico City plant is based on actual experience. Back in 1942 we opened a plant in the Argentine. This may test your credulity, but our records show that for a period of several months after we opened the Argentine plant, sales dropped by 50%. There is the bright side, of course. Once we got underway in the Argentine and the Argentinians were convinced that Gillette products made in Argentina were every bit as good as Gillette products made in the U.S.A., our sales rose three times above the best year we had ever had in the Argentine.

As late as the recent war years this distrust for products not made in the U.S.A. showed itself again. When the greater portion of our products was being supplied to the men in the armed services, it became necessary for us to supply certain countries in South America — Colombia and Venezuela to be exact—with blades made in our Argentine factory. Prior to this those countries had been supplied from our Boston plant. We shipped several million blades to those countries from the Argentine. They bore the imprint "Made in Argentina." Again records show that it was most difficult to move those blades.

I don't want to give you the impression that it is only in the Latin and South American countries where this great admiration for American products exists. The same is true in Europe. Again our experience supports this statement. Before we opened our factory in Paris, France was supplied blades from the Boston factory. On one occasion it became necessary for us to ship from our Montreal plant, and with the blades stamped "Made in Canada," we had the same experience in France as the one I have just related to you regarding Colombia and Venezuela.

There are other examples, many of which dramatically illustrate the desire by peoples in foreign countries for quality-made American products. Other manufacturers who have built plants in foreign lands have had experiences similar to our own. All these experiences show that there is no substitute for quality.

THE MARK OF QUALITY

This nation is known throughout the world for its industrial know-how. It is known throughout the world for the quality of the products this know-how turns out. You people have made a definite and valuable contribution to the quality of the products which have made this nation the industrial leader of the world.

Quality products, as I said before, cannot be made and sold without the stamp of quality being affixed to every step in the manufacturing and marketing process. Certainly by now this has become evident to the peoples in foreign lands. If they examine into the reasons why this nation has forged into industrial and quality leadership, as I feel they have, then they must come to but one conclusion. The mark of quality must be an inherent part of our competitive, free enterprise system. Our standard of living, higher than that achieved by any other nation in the history of man, is a still further indication of this.

There can never be a substitute for quality whether in the manufacture of a better mousetrap or in the political ideology which has made a nation of free people great and strong.

Operating Characteristics of Average and Range Charts*

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1. INTRODUCTION

The statistical control of industrial processes by means of Shewhart control charts is largely an **empirical** science. Many handbooks and working manuals on the control chart methods contain a passing reference to the existence of an underlying mathematical theory, and advise the interested reader to seek it elsewhere. However, not much of the theoretical basis has ever been published. Further theoretical development seems desirable even though the methods have been so successfully applied without this. It permits other answers than those beginning "Experience indicates . . ." to questions arising in certain situations where charts are being used or considered; for example, questions as to appropriate sample size, or the suitability of the customary "three-sigma" control limits, etc. We do not claim that such decisions should be based only on theoretical considerations, but merely that one can have more confidence in decisions made in the light of theory than in the dark. This paper is intended as a step toward further developing the theory.

The theoretical basis of these or any other statistical methods is to be sought in the mathematical theory of probability. The property of a statistical method generally considered most important by the theoretician is its **operating characteristic** (abbreviated OC). Quality control engineers are thoroughly familiar with the notion of the OC of an acceptance sampling plan for attribute sampling. In that case the probability that a lot with a proportion p of defective items will be rejected by the plan is a function of p; this function is the OC of the plan, and its graph is the OC curve. (It is customary in the case of acceptance sampling to use the probability of acceptance rather than the probability of rejection; the latter is more convenient with the control charts, and we want to preserve the analogy. Of course if we know one, we know the other, since they must add up to unity). While the OC does not tell the whole story of the action of an acceptance sampling plan, it is usually the most useful single tool for analyzing the plan: the only rational way of comparing the effects of two different sampling plans involves a comparison of their OC's.

EDITOR'S NOTE

Some of the symbols appearing in this paper, although standard in the general literature of statistics, have seldom or never appeared before in IQC. Because they may therefore be new, and hence unfamiliar, to our readers, we give the following glossary.

$|m—m'|$ — The absolute or numerical value of the difference; thus, $|4—6| = 2$.

κ — Lower case Greek letter "kappa."

ϱ — Lower case Greek letter "rho."

τ — Lower case Greek letter "tau."

$>$ — Symbol meaning "is greater than," or simply "greater than."

$<$ — Symbol meaning "is less than," or simply "less than."

$\Pr[R>D_2\sigma']$ — Read this as "The probability that R is greater than $D_2\sigma'$".

In control chart practice two different but related phases are distinguished; one[2] is called "control with no standard given," the other, "control with respect to a given standard." We shall discuss the OC's for the case where a standard is given and where the quality characteristic being controlled in the sequence of items produced is one that can be measured on a continuous scale; for example, the diameter of a shaft. This quality characteristic will be denoted by X; it varies from item to item in the sequence being produced. "Giving a standard" means specifying a mean and standard deviation for X. Of course such a standard is not just dreamed up but is set in the light of the analysis of past results with the process or a similar process; we set a standard which we have some hope of attaining. The specified mean and standard deviation are customarily denoted by $\bar{X}'$ and σ', but we shall denote them by m' and σ'.

The control chart procedure for control with respect to the given standard is to take a sample of n items from the process at more or less regular time intervals, perhaps a sample of 5 successive items about once an hour. The average $\bar{X}$ and the range R of the sample are immediately calculated and plotted on two control charts, each consisting of a horizontal time-axis, a vertical $\bar{X}$ and R-axis, and a pair of horizontal control lines. The control lines for the $\bar{X}$-chart are set according to the formulas (UCL denotes "upper control limit," etc.)

$$(UCL)_{\bar{x}} = m' + A\sigma',$$
$$(LCL)_{\bar{x}} = m' - A\sigma',$$

where, for so-called "three-sigma limits" the factor A is listed in well-known tables[3]; it is actually $A = 3/\sqrt{n}$. More generally, for k-sigma limits it would be $A = k/\sqrt{n}$. The upper control line for the R-chart is placed at a certain multiple of σ', say $D_2\sigma'$:

$$(1) \qquad (UCL)_R = D_2\sigma'.$$

For three-sigma limits D_2 is listed in the

* An invited address given at a joint meeting of the Institute of Mathematical Statistics and the California Section of the American Society for Quality Control, San Diego, June 18, 1947.

[2] For a discussion of the relation of this phase of control chart practice to analysis of variance and chi-square tests, see Scheffe' **Journal of the American Statistical Association,** vol. 42 (1947), pp. 425-431.

[3] Appendix 1, pamphlet Z 1.3, American Standards Association, New York, 1942.

standard tables mentioned above. For k-sigma limits it may be calculated easily from the same tables[4].

The reader's attention is called to our use of the symbols A and D_2 in a different way from that to which he may be accustomed: We repeat that we use them for general k-sigma limits, whereas ordinarily these symbols are restricted to three-sigma limits. To simplify the discussion we shall assume the lower control limit on the R-chart is always taken at zero[5]. As long as the plotted points fall within the control lines the process is not interfered with, but as soon as a point on either chart goes outside the control lines the process is stopped, the judgment is made that the process is not in the desired state of statistical control, and the cause of the supposed trouble is sought, and, if possible, eliminated. This is a somewhat simplified version of what is really done, but even so the following discussion may seem complicated enough to some readers.

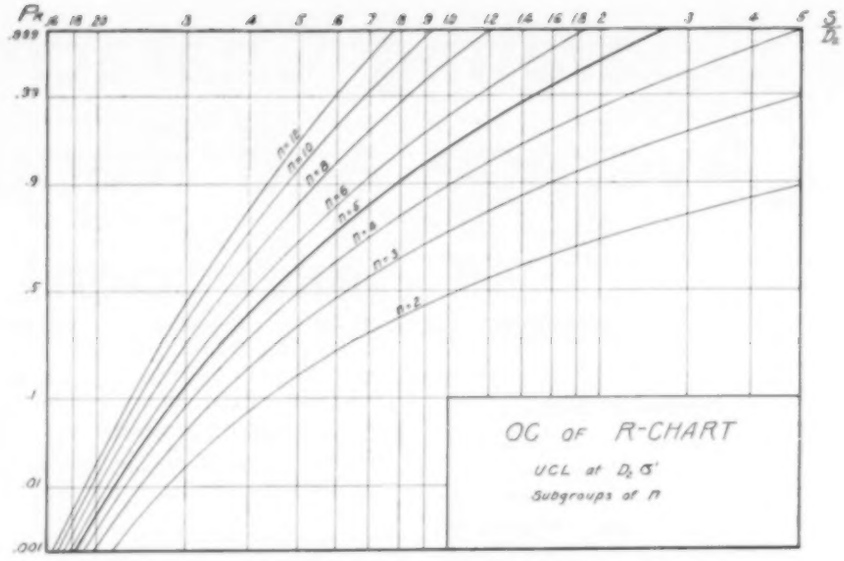


FIGURE 1 — OPERATING CHARACTERISTICS FOR THE R-CHART

2. ASSUMPTIONS

The OC of the control chart method may now be defined by analogy with the familiar concept of the OC of an acceptance sampling plan. Just as with an acceptance sampling plan we accept or reject the **lot** on the basis of a sample from the lot, we may likewise say that with the control chart method we accept or reject the **process** every time we plot the points on the charts, according as both points are inside their control lines or not. Just as the OC of an acceptance sampling plan is the probability of rejection of the lot, considered as a function of the lot quality p, so with a control chart the OC is the probability of rejection of the process, that is, the probability that the plotted point go outside its control lines, considered as a function of the state of the process. (We could consider the joint OC of the two charts but it is more convenient to consider the OC's of the two charts separately). The complete OC of a control chart would tell us for every possible state of the process what is the probability that the point on the chart go outside the control lines when the process is in this state.

Here we encounter something that is inherently much more complicated for processes than for lots. For the purpose of discussing acceptance sampling plans the state of a lot can be completely characterized by a single number p, namely the proportion of defectives in the lot. But the possible states in which a process might be have a variety that staggers the imagination. The complete OC would involve calculating the probability of rejection for all these possible states of the process, and since it is not feasible even to catalogue them, we must be contented with a partial determination of the OC, say for a relatively small number of states which may be of some practical interest. The situation is akin to that of having to determine the topography of a region which has never been mapped before. We can't determine the elevation at **every** point of the territory, but we must get along with what we can conveniently get: an incomplete mapping that takes into account some points of practical interest is far superior to no mapping at all.

The incompleteness of our description of the OC's of the control charts lies in the fact that we shall restrict ourselves to those cases in which the sample of n may be regarded as a **random sample** from some **normal** population, not necessarily that with the mean m′ and standard deviation σ′ specified by the standard. Under this assumption, if the process is in the specified state of statistical control, the sample will then be from a normal population with mean m′ and standard deviation σ′, and we consider only those deviations from the specified state of statistical control in which the process may be represented by another normal population, say with mean m and standard deviation σ. One heavy restriction in our calculations is that we assume that the normal curve describing the process does not change while the sample is being taken.

Even with all these simplifications there are still six parameters entering our calculations: the specified mean m′, the specified standard deviation σ′, the true mean m, the true standard deviation σ, the sample size n, and the constant k or D_2 which depends on whether three-sigma limits or some other limits are used on the chart.

It is accordingly a relief to find that it is possible to take all these parameters into account and yet have only a single diagram for the OC's of all $\bar{X}$-charts and another for all R-charts. This is accomplished by using two measures, which we shall denote by S and T, for the departure of the process from the state specified by the standard:

$$S = \sigma/\sigma',$$
$$T = |m - m'|/\sigma'.$$

We may think of the letter S standing for "spread"; it is the ratio of the true standard deviation of the process to that specified by the standard. The other letter T may stand for "translation"; it is the amount the true mean of

[4] For k-sigma limits take the upper control limit at $d_2 + k(D_2 - d_2)/3$, the lower control limit at $d_2 - k(D_2 - d_2)/3$ unless this is negative, when it is replaced by zero; the d_2 and D_2 of these formulas are those listed in the tables.

[5] If the lower control limit is not zero but positive, call it $D_1\sigma'$. The probability that the point on the R-chart fall below the LCL may then be found by following the directions to be given below (Section 3) for determining the probability that the point fall above the UCL of the R-chart, but replacing D_2 of those directions by D_1, and finally subtracting from unity the probability thus found.

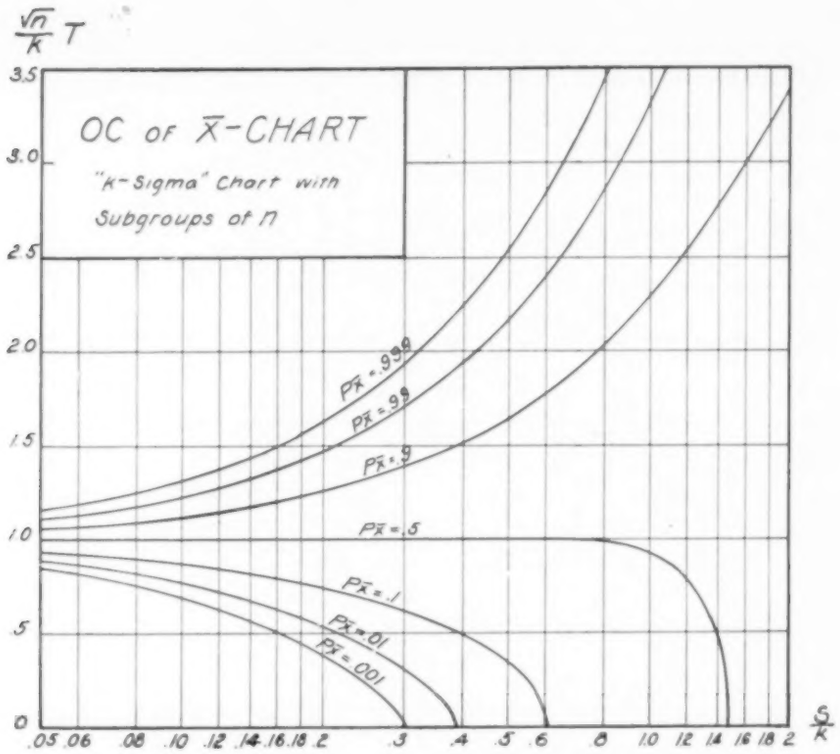


FIGURE 2 — OPERATING CHARACTERISTICS FOR THE $\bar{X}$-CHART

the process is shifted from that specified by the standard, measured in units of the specified standard deviation.

3. GRAPHS OF OC'S

The OC of the R-chart is pictured in Figure 1. Along the vertical axis we have the probability P_R that the process will be rejected on the basis of the R-chart, that is, the probability that the point on the R-chart will fall above the upper control line. This does not depend on the translation T but only on the spread S. If we plot along the horizontal axis not S but S/D_2, then the same diagram can be used for all settings of the upper control line: we recall from (1) that D_2 determines the upper control limit on R. The different OC curves on Figure 1 correspond to different sample sizes n.

To illustrate the use of Figure 1, suppose the popular sample size $n = 5$ is used and that the value of D_2 is that given in the standard tables for three-sigma limits, namely $D_2 = 4.92$. Let us ask first what is the probability of rejection of the process on the basis of the R-chart if σ has its specified value σ'. Then $S = 1$, $S/D_2 = 1/4.92 = .20$. On the curve for $n = 5$ we read that for $S/D_2 = .20$ the probability P_R is somewhere between .001 and .01 (this is sufficiently accurate for most industrial purposes where merely an order-of-magnitude statement is usually wanted).

We might ask next how large the spread S of the process has to be before there is an even chance ($P_R = 1/2$) of its being detected on a single application of the R-chart. For $n = 5$ we find that if $P_R = 1/2$ then $S/D_2 = .45$, or $S = .45\ D_2 = (.45)(4.92) = 2.2$. This means that the standard deviation of the process has to increase to 2.2 times its specified value before there is a 50% chance that trouble will be indicated by the R-chart.

If this is not satisfactory, that is, if we want a higher probability that such a spread will be indicated by the R-chart, there are two things we can do. One is to set the UCL lower, that is, to use a smaller D_2. This is done at a price, however, for then we also increase the probability of looking for trouble when there isn't any. To give a concrete example of this effect, suppose we want a probability of .9 of detecting a spread S as large as 2.2. On the curve for $n = 5$ we find $P_R = .9$ when $S/D_2 = .80$, so that $D_2 = S/.80 = 2.2/.80 = 2.75$. However, if we set the UCL with $D_2 = 2.75$, then when $S = 1$, $S/D_2 = .36$, and from the same curve $P_R = .3$ for this value of S/D_2. This means that with such a setting of the UCL the R-chart would indicate trouble about 30% of the time when the standard deviation has its specified value, and this would of course be intolerable. We have here a typical situation arising when we have to choose a statistical method. Two kinds of errors are possible: in this case we may look for trouble in the process where there isn't any, or we may ignore trouble when it exists. For a fixed sample size[6] we can in general reduce the risk of one kind of error only at the expense of increasing the risk of the other kind.

The other thing we can do to get a higher probability that the R-chart will detect a spread of 2.2 is to increase the sample size. Thus if we take sample size $n = 12$ and require a probability of .9 of detecting a spread of 2.2 we find, proceeding as before but using the curve for $n = 12$, that we would have to take $D_2 = 5.0$ and that then the probability of R exceeding its UCL when $S = 1$ would be about .02. In quality control work this would usually be considered too large a risk of looking for non-existent trouble, and so with $n = 12$ we would be likely to take D_2 a little larger. Our object here is not to decide on the D_2 that might be appropriate in a given situation, but rather to make clear that whatever D_2 and n are considered, the effects of using the resulting R-chart are computable from its OC which is graphed in Figure 1.

We turn now to the OC of the $\bar{X}$-chart. This is harder to picture because the probability $P_{\bar{x}}$ of rejection depends on both the spread S and the translation T. To picture the function $P_{\bar{x}}$ geometrically we would have to plot it as the ordinate to a surface above an S, T-plane. Figure 2 shows certain contours of this surface which are of interest. Suppose k-sigma limits are used on the $\bar{X}$-chart with sample size n. It turns out that if instead of plotting S along one scale we plot S/k, and instead of plotting T along the other scale we plot $T\sqrt{n}/k$, then the same contours are valid for all k and n.

To exemplify the use of Figure 2 we might consider the chance of detecting various shifts of the mean when the standard deviation has its specified value so that $S = 1$. If we use a three-sigma chart with sample size 5, then

[6] And for a fixed statistic used as criterion by the statistical method (in this case the statistic is the range R).

$k = 3$, $n = 5$, $S/k = 1/3$, so that when the mean shifts we run up and down the vertical line $S/k = .33$. If the mean has its specified value, then $T=0$, and we read that $P_{\bar{x}}$, the probability of rejection, is somewhere between .001 and .01 (it is actually about .003). If the mean shifts a distance equal to half a standard deviation, then $T=1/2$, $T\sqrt{n}/k = 1/2\sqrt{5}/3 = .37$, and we read that $P_{\bar{x}}$ is less than .1.

It is of interest to see how the $\bar{X}$-chart reacts to change of standard deviation when the mean has its specified value. In this case we run along the lower edge of the diagram where $T = 0$. We might ask how much the standard deviation has to increase from its specified value before there is an even chance of it causing rejection on the basis of the $\bar{X}$-chart. We find when $T = 0$ that $P_{\bar{x}} = 1/2$ for $S/k = 1.5$, so that with $k=3$, the spread S must equal 4.5. It thus takes quite a large spread of the standard deviation for there to be much chance of its showing up on the $\bar{X}$-chart. An interesting phenomenon indicated by this calculation, where we run along the lower edge of Figure 2, is that the sensitivity of the $\bar{X}$-chart to spread of the standard deviation is independent of sample size: when the translation $T=0$, $P_{\bar{x}}$ depends on S and k but not on n.

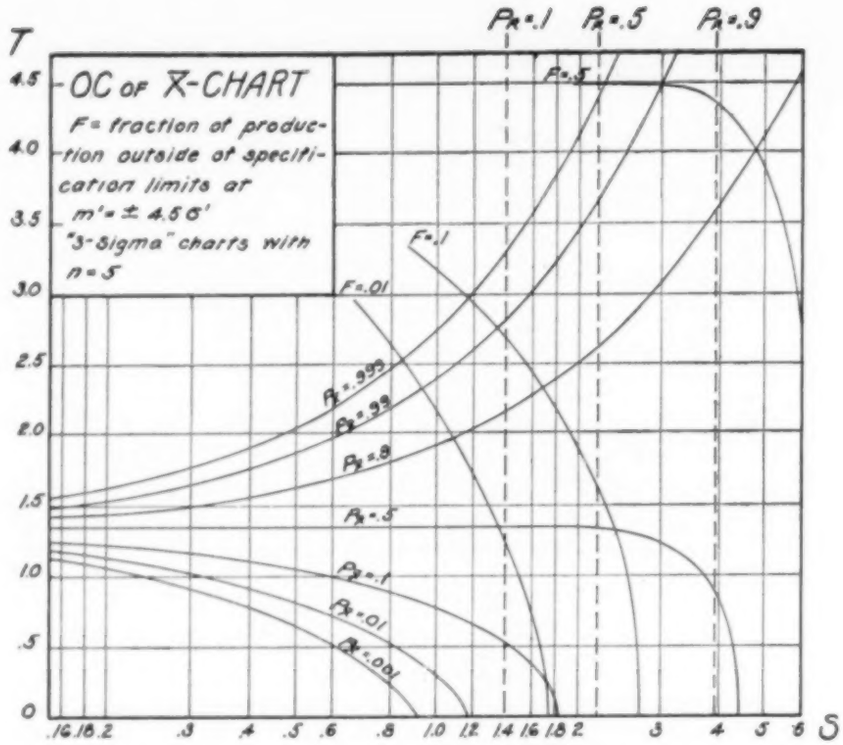


FIGURE 3 — OPERATING CHARACTERISTICS FOR THE $\bar{X}$-CHART FOR THE SPECIAL CASE $n = 5$, $k = 3$, $\kappa = 4.5$

4. A CRITERION FOR JUDGING AN (S, T) PAIR

A question which may already have troubled the reader is this: every pair of values (S, T) represents a possible state of the process. For some of these pairs (S, T) we would like the charts to indicate trouble, and for some, not. How important is it, for a given pair of values (S, T), that trouble be indicated or not indicated? This depends on the tightness of the specifications to which we would like the process to conform; the tighter the specifications, the less we can afford to have the mean wander off or the standard deviation increase from their specified values.

We can get a numerical measure of how objectionable a given pair of values (S, T) is by considering the fraction F of bad production they cause. This fraction F is arrived at as follows. Suppose acceptable values of the quality characteristic X are defined by a pair of specification limits LSL and USL, such that any X falling in this interval is satisfactory, and any X falling outside is not. We recall that the state of the process is assumed to be represented by a normal curve with mean m and standard deviation σ. We define the fraction F of bad production to be the area under this curve and outside the interval between the specification limits. We can now use F as a criterion to judge a given pair of (S,T) values: if the F for the pair is high, this pair is undesirable; if the F is low the pair is acceptable.

The same Figure 2 can be employed to find the F value which expresses how good or bad any (S,T) pair is, **providing** the specified mean m′ is set midway between the specification limits. In that case the specification limits can be expressed as m′ plus or minus a certain multiple κ of σ′,

$$\text{(2)} \qquad \text{USL} = m' + \kappa\sigma', \qquad \text{LSL} = m' - \kappa\sigma'.$$

For any given (S,T) the fraction F is the same as the $P_{\bar{x}}$ we read from Figure 2 if we enter with $n = 1$ and k equal to κ.

To illustrate this, suppose that in a certain application of the control chart method the distance between the specification limits is equal to 9 times the specified standard deviation σ′, and that the specified mean m′ of the given standard is set midway between LSL and USL, so that $\kappa = 4.5$. The reader may recall that for sample size 5 we calculated that there was only a small chance (less than .1) of detecting a half-sigma shift of the process from the specified mean when the standard deviation remained fixed at its specified value; this state is represented by (S,T) $= (1, 1/2)$. To find how important it is in the present application to detect a deviation of this amount from the given standard we calculate the fraction F from Figure 2. In place of k we use $\kappa = 4.5$, so we enter on the horizontal scale with $S/\kappa = 1/4.5 = .22$; for the vertical scale we take $n = 1$ and enter with $T/\kappa = .5/4.5 = .11$; the result is that we find F is considerably less than .001. In this case we are quite happy about the $\bar{X}$-chart's not being sensitive to such a deviation; with tighter specifications we would find a larger F and perhaps feel less happy.

In order to judge whether, for a given situation, the OC of the $\bar{X}$-chart is satisfactory or not we would like to have the F-contours graphed on the same axes as the $P_{\bar{x}}$-contours (with perhaps also some P_R-contours on the same axes). Such a diagram will be valid only for some particular values of n, k, and κ (and D_2 if the P_R-contours are on the same axes), since the $P_{\bar{x}}$-contours are taken from Figure 2 with one pair of scales on the axes, the F-contours are taken from Figure 2 with a differ-

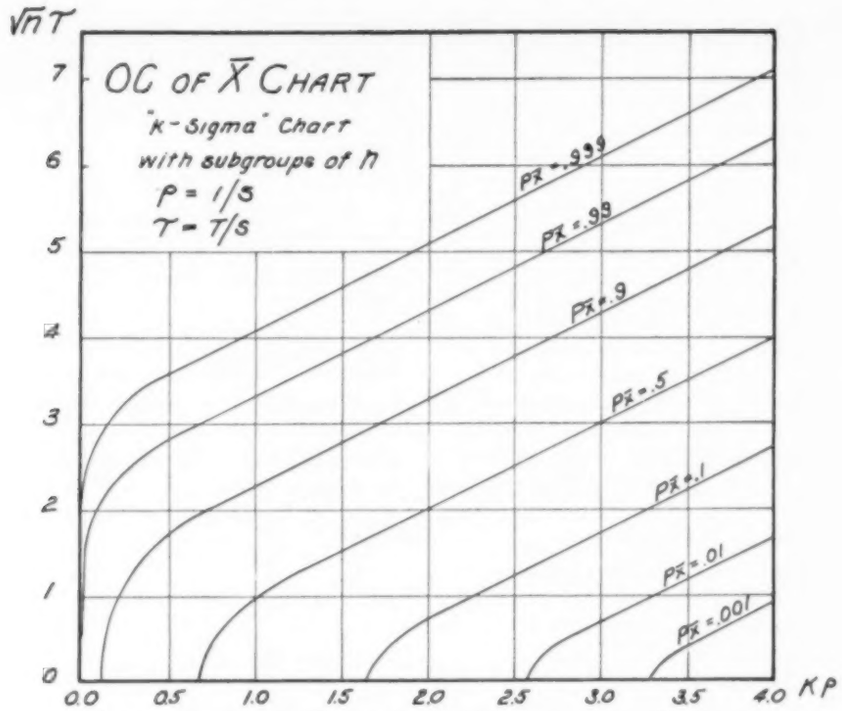


FIGURE 4 — OPERATING CHARACTERISTICS FOR THE $\bar{X}$-CHART WITH $P_{\bar{x}}$ IN TERMS OF (ϱ, τ) RATHER THAN (S, T) VALUES

ent pair of scales, and the relation between the scales depends on n, k, and κ.

We have constructed such a diagram in Figure 3 for the situation already considered where $n=5$, $k=3$, $\kappa=4.5$. We emphasize that Figure 3 is valid **only** for the above values of n, k, and κ. If on Figure 3 we follow the contour $F = .5$, we pass through all possible (S,T) values for which the fraction of bad production is .5. On this contour we find that for S less than 4.8 the probability that the $\bar{X}$-chart will indicate trouble is over .9; on the other hand, for S values greater than this the probability that the R-chart will indicate trouble is over .9, as indicated by the dashed vertical contours for the R-chart on the same figure. The P_R-contours in Figure 3 are for $n = 5$ and $D_2 = 4.92$ (the three-sigma value), and are calculated from Figure 1.

Figure 3 indicates how the $\bar{X}$ and R-charts complement each other; thus, along the contour $F = .5$ we have seen that where one chart is poor the other is good. To continue with this example (where the specification limits are at $m' \pm 4.5\sigma'$) we remark that usually one would like a good probability that the charts indicate trouble if the process is in a state where the fraction F of bad production is 10%. If we follow the contour $F = .1$ on Figure 3 we see that if only an $\bar{X}$-chart were used the probability of detecting trouble would drop below .5 for some states with $F = .1$ (namely those with $S > 2.5$), but that for such states the probability that the R-chart indicate trouble is greater than .5. It can be shown[7] that the probability that at least one of the two charts indicate trouble, in this example when $F = .1$, is always greater than .78, although $P_{\bar{x}}$ drops below .3 at the bottom of this F-contour.

5. CONCLUDING REMARKS

Figure 4 is another picture of the OC of the $\bar{X}$-chart. The mathematical function whose value is $P_{\bar{x}}$ is better behaved if it is expressed in terms of certain parameters (ϱ, τ) instead of (S,T), and the contours for $P_{\bar{x}}$ are seen to have a more regular shape on Figure 4 than on Figure 2, facilitating interpolation when necessary. (The contours straighten out toward the right and cut the right edge of the diagram at intervals which are proportional to those on normal probability graph paper.) The parameter ϱ may be regarded as the reciprocal "spread," while τ may be regarded as the "translation" measured not in σ' units but in σ units,

$$\varrho = \sigma'/\sigma, \qquad \tau = |m - m'|/\sigma. \tag{3}$$

If (S,T) are given, (ϱ,τ) are easily found, and conversely; the relations are

$$\varrho = 1/S, \quad \tau = T/S, \quad S = 1/\varrho, \quad T = \tau/\varrho.$$

The reason we have used (S,T) instead of (ϱ, τ) in the preceding discussions is that they express in a more direct way how far the process has wandered away from the state specified by the given standard. Of course, Figure 4 may also be used instead of Figure 2 to find the fraction F of bad production, by entering with $n = 1$ and $k = \kappa$.

We shall conclude with two remarks which may be helpful. The first refers to the term "fraction F of bad production." We wish to make it clear that F is not the actual fraction of bad production by the process during some given time interval; the F calculated from the pair of values (S,T) describing a possible state of the process is what the fraction of bad production would be in a long run of the process **if it stayed** in this state (and if the output behaved like random sampling from a normal population).

The other remark concerns what the reader may have judged to be a rather poor sensitivity of the control chart methods brought out by the OC's. It is important to remember in this connection that the control chart method for controlling a process does not consist of plotting a single point on each chart but a succession of many points. If there is only an even chance of the charts indicating trouble on a single application, and if eight applications are made in a day, the probability is over .996 that trouble would be indicated at least once during the day. For similar reasons it is usually desirable to set the control lines far enough apart so as to keep extremely low the probability that the charts indicate trouble when the process is in the state of statistical control specified by the given standard.

It is a pleasure to acknowledge our indebtedness to Dr. A. E. R. Westman for some very helpful criticisms.

6. MATHEMATICAL APPENDIX

The probability P_R that the range R will exceed its UCL at $D_2\sigma'$ is

$$P_R = \Pr[R > D_2\sigma'] = \Pr[R/\sigma > D_2\sigma'/\sigma],$$

$$P_R = \Pr[w > D_2/S], \tag{4}$$

where $w = R/\sigma$. The probability that

[7] By numerical calculation based on formulas (4), (6), (7), and (8) of the mathematical appendix.

$w \leqslant w_0$ is tabled for various n and w_0 by E. S. Pearson in **Biometrika,** vol. 32 (1942), pp. 302-307. From equation (4) we see that for fixed n the same graph is obtained for P_R independent of D_2 if P_R is plotted as a function of S/D_2 instead of S. If the LCL for R is not set at zero but at $D_1\sigma'$, we find in a similar way

(5) $\quad Pr\,[R<D_1\sigma'] = 1-Pr\,[w>D_1/S]$.

This probability may thus be found from the same curve as P_R by following the directions in footnote 5.

The probability that $\bar{X}$ will exceed its UCL set at $m'+k\sigma'/\sqrt{n}$ may be calculated as follows. The mean of $\bar{X}$ is m and its standard deviation is $\sigma/\sqrt{n}$, hence $u = \sqrt{n}(\bar{X}-m)/\sigma$ is a standard normal deviate.

$$\begin{aligned} Pr[\bar{X}>UCL] &= Pr[\bar{X}>(m'+k\sigma'/\sqrt{n})] \\ &= Pr[\sqrt{n}(\bar{X}-m)/\sigma > \\ &\quad (\sqrt{n}[m'-m]/\sigma+k\sigma'/\sigma)], \\ &= Pr[u>(\sqrt{n}\tau+k\varrho)], \end{aligned}$$

where ϱ and τ are defined by (3). We assume $m' \geqslant m$; if $m' < m$ the same expression as (6) below is obtained for $P_{\bar{x}}$ from considerations of symmetry. In a similar way we find

$$Pr\,[\bar{X}<LCL] = Pr\,[u<(\sqrt{n}\tau-k\varrho)].$$

The probability that $\bar{X}$ fall outside its control limits is the sum of the probabilities of the mutually exclusive events $\bar{X}>UCL$ and $\bar{X}<LCL$, hence

(6) $\quad P_{\bar{x}} = Pr[u<(\sqrt{n}\tau-\kappa\varrho)] + Pr[u>(\sqrt{n}\tau+\kappa\varrho)]$.

For given u_0, $Pr[u \leqslant u_0]$ is tabulated in many tables of the normal probability integral. Formula (6) for $P_{\bar{x}}$ indicates why $k\varrho$ and $\sqrt{n}\tau$ are plotted along the axes of Figure 4. If we substitute for ϱ and τ in (6) in terms of S and T we see that $P_{\bar{x}}$ depends on S/k and $\sqrt{n}\,T/k$, but not otherwise on n or k: this explains why these quantities are plotted in Figure 2.

Since $\bar{X}$ and R are known to be independently distributed, it follows that the probability that at least one of the two points $\bar{X}$ and R go outside its control limits is

(7) $\quad 1-[1-P_{\bar{x}}][1-P_R]$.

If the LCL on the R-chart is not at zero, P_R should be replaced in (7) by the sum of the expresisons (4) and (5).

The fraction F of bad production is the probability that a normal variable X with mean m and standard deviation σ fall above USL or below LSL. Proceeding as toward (6), and utilizing (2), we find

(8) $\quad F = Pr[u<(\tau-\kappa\varrho)] + Pr[u>(\tau+\kappa\varrho)]$,

where u is a standard normal deviate. This is of the form (6) with n replaced by 1 and k by κ.

The Place of the American Society in Modern Quality Control*

WADE R. WEAVER

VICE PRESIDENT, AMERICAN SOCIETY FOR QUALITY CONTROL

As we reach the third milestone in the history of our Society it is fitting that we should view, in retrospect, certain important facts. Not always was the niche in which the American Society for Quality Control finds itself today so securely occupied, for in the period immediately prior to the formation of the the Society there were many who felt that there existed no true place in the field for such a Society. The concepts in question were primarily statistical, so their promulgation rightfully belonged to the statistical field. But some of us felt differently; believed strongly in the potential future of a Society devoted to the principles of controlling quality **by whatever means,** and so there ensued weeks and months of almost endless discussions, consultations, conferences and meetings, and February 16, 1946 saw the birth of the American Society for Quality Control, comprising 19 local Sections and some 1186 members.

Those were trying times that first year. On numerous occasions the Executive Committee labored long into the small hours of the morning and resumed at 9:00 A. M. trying to formulate policies and build soundly. How to obtain members? Frankly, finances were a problem. There was much work to be done and important decisions to be made. Many individuals devoted time and effort, and several corporations aided generously with secretarial services and by approving travel expense accounts. In due time we were able to hold the First Annual Convention at Chicago in June, 1947. The Treasurer's report showed that we were technically bankrupt; but our spirits most certainly were not. By this time we had about 1821 members in 25 local Sections, a magazine that was attracting considerable attention, and the words "quality control" were being heard in places other than the councils of the Sections.

The second year was, in many respects, even more difficult than the first. Thinking in various parts of the country differed, policy was therefore not simple to formulate, and progress was not always as smooth nor as rapid as desired. In February, 1948, the Second

* Presented at the Third Annual Clinic and Gage Exhibit, St. Louis Section, November 19, 1948.

Annual Convention was held in Rochester, and for the first time our Treasurer's face wore a smile. We had 29 Sections with 2000 members, and **money in the bank!**

At the Third Mid-West Conference in Chicago, November, 1948, the Executive Committee heard the reports of the Secretary and Treasurer; a membership of 2101 at the end of the 1948 fiscal year, comprising 31 local Sections, and $7,440 in the bank. A tentative operating budget for the year 1949 of $19,870 was approved. Few, if any, technical societies have ever equalled the rapid growth experienced by ASQC. We can confidently and proudly state that the Society has survived the rigors of getting established and has, despite the pessimism of many, proven that it is here to stay.

Many may wonder about the place of the American Society in the modern field of Quality Control. Just what does it have to offer its members? What can it do for industry and the thousands who are interested? How does it help, and whom?

First of all, there is Industrial Quality Control, our official publication. Starting as a 4-page mimeographed edition in 1944, it was carefully nurtured by Dr. Martin A. Brumbaugh, its originator, to 20 pages per issue by January 1946. With the founding of ASQC, it became the official journal of the Society operating under an Editorial Board of 12 (now 14) leading authorities in the field of statistical quality control, with Dr. Brumbaugh as Editorial Chairman. By May 1946, the magazine had expanded to 32 pages where, under the continuing direction of the Editorial Board and the Editorial Chairmanship of Mason E. Wescott who succeeded Dr. Brumbaugh in this capacity in July, 1947, it has since served admirably the technical publication needs of the Society.

Always a dignified and conservative publication, Industrial Quality Control has come to be recognized as an authoritative source of quality control information. Its present circulation reaches all parts of the United States as well as Canada and numerous foreign countries. Herein are published what the Editorial Board considers to be the best available articles on timely quality control topics. Its bi-monthly appearance is augmented on alternate months by the News Supplement, edited by Mr. E. H. Robinson, which provides for local Section news and gossip, items of general interest, and periodic calendars of meetings, programs, and speakers.

In June 1947, the Executive Committee took action to establish the Shewhart Medal, thus honoring Dr. Walter A. Shewhart, the only* honorary member of the Society to date, who, in 1924, originated the concepts of modern statistical quality control. Not oftener than once each year a medal will be awarded to an individual chosen by the Medal Committee for his outstanding contribution to the development of quality control principles or their application to industry. It is expected that the award to the Society's first Medalist will be made at the Third Annual Convention of ASQC in 1949.

Following the Fourth Annual Rochester Clinic in 1948, the Rochester Section made a sustaining contribution of $2000 to the Society, with the suggestion that half this sum be set aside to establish the Martin A. Brumbaugh Award. The Executive Committee stood in full agreement with the Rochester Section in recognizing the appropriateness of thus perpetuating the name of one of the Society's most distinguished members. Accordingly there was appointed the Brumbaugh Award Committee, charged with the responsibility of selecting the best paper published in Industrial Quality Control each year and suitably recognizing its author. As soon as the Committee has formulated appropriate procedures for activating its responsibilities, the selection of the first Brumbaugh Award paper will be made and announced.

Thus does ASQC provide incentive for its members and take cognizance of meritorious achievements.

The Constitution of ASQC provides three classes of membership in a sincere effort to bestow professionalism upon those duly qualified. The importance of this will be more fully recognized as the field of quality control develops and expands. It will soon be a privilege to be a Senior Member.

We have a Standards Committee, ably led by Harold F. Dodge, which is currently engaged in standardizing terms, nomenclature, coordinating procedures, etc., so that all users of quality control techniques can be provided with uniform terminology and concepts.

The Committee on Relations with Educational Institutions is performing a valuable service by collaborating with those interested in training courses, and by furnishing suggestions gleaned from the field. It becomes increasingly more important that new students of quality control should be taught the modern applications and diversifications of thinking. The scope is so rapidly widening that even trained individuals soon find it difficult to keep pace. Hence, properly designed and presented educational courses are of extreme importance.

Because the application of quality control principles is extending into so many fields and technical services, other technical societies and their members are becoming increasingly interested in us. The Committee on Relations with other Technical Societies is fitting admirably into this situation by collaborating with such societies in arranging joint meetings, suggesting topics, providing qualified speakers, etc.

Clinical meetings of the type which have been held all around the country provide excellent opportunities for those interested to learn the fundamentals and hear the case histories of industry. Those attending have an opportunity to meet and talk with others in their own or similar and allied fields, to discuss problems, and to seek and give advice. Even more elaborate and far reaching in their effects are the Regional Meetings, for these bring together most of the talent in a given geographical area and thus provide for an even wider exchange of ideas. Top management is becoming vitally interested in such meetings, and is participating in them. Manufacturers of the latest in gaging equipment and other mechanical aids to quality control are afforded opportunity to bring such items to the attention of the right people; individuals in need of such mechanical aids are similarly benefited.

Very little, if any, of all of this would be possible today if it were not for the American Society and its consolidation and co-ordination of such matters. Your Executive Committee has additional long range plans in mind and is merely awaiting the propitious time to launch them. Plans for expansion of Industrial Quality Control, largely dependent upon financial considerations, are being discussed.

We have every right to be truly proud of our Society, but we must also realize our responsibilities to it. Let each member herewith resolve to do his part in the further strengthening and building for the future.

* See pages 25 and 29.

The Case of the Perjured Control Chart

V. E. McCOUN

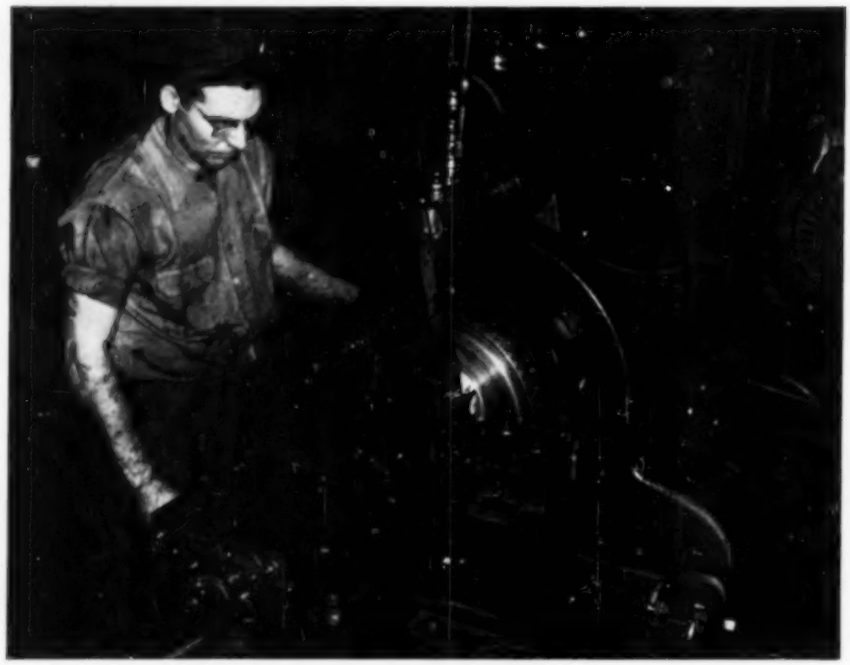
QUALITY CONTROL ENGINEER—INTERNATIONAL HARVESTER CO.
TRUCK ENGINE WORKS, INDIANAPOLIS, INDIANA

All mystery stories must, perforce, have a beginning. This story begins when the quality control group at our engine plant received a request from the foreman of the flywheel department for a quality investigation of one of the machine operations in his department.

The machine tool in question was an automatic, multiple-tooled lathe. The request stated that over a considerable length of time a great deal of trouble had been experienced in maintaining size on the large outside diameter of the flywheel, (approximately 14.625 inches), the result being excessive scrap and rework, high tool cost, lost production due to tool changes and adjustments, payment of allowances to the operator, and overtime to maintain the schedule.

Our first attack was the application of a control chart for variables, taking samples of five consecutive pieces, at approximately one hour intervals. Of course we had to devise a suitable gaging medium for taking actual measurements. The regular production gage was a go, no-go length gage. After accumulating 19 samples through a two day period, an $\bar{X}$ and R chart was set up. (See Figure 1). The range showed a very stable pattern with all points in control, but the sample averages fluctuated wildly from one group to the next. This, however, we expected, since the tool had been reset, **without using the new gage,** from one to five times between each sample and the next.

The indicator was calibrated in .0001 of an inch. Coded values were used, the code being 1=.0001". With $\bar{R}$= 8.2 and d_2=2.326, the relation $3\bar{R}/d_2$ gave a predicted plus or minus three standard deviation spread of 10.6, which compared very favorably with the specification limits of plus or minus 20.



DEPARTMENT 14 — OPERATION 15 — FLYWHEEL, MODEL BLD.
Note indicator on overarm from head stock housing to check variation in tool block travel.

Being thus encouraged, we arranged for the operator to run the machine through one entire shift without changing the tool setting. Samples were again taken as before and charted. We were pleased to find an excellent pattern of control showing on the chart (See Figure 2) but alas, the individual pieces, when checked, were not only beyond the indicated statistical limits: they did not even conform to the engineering limits! The operation was continued next day with an observer posted at the machine to make sure that the tool was not changed and through a four hour period the same results developed: the chart, good; the pieces, no good.

We then made a consecutive check of 100 pieces from the operation, again without touching the tool, and charted the results. (See Figure 3) Imagine our surprise: an increasing and decreasing cycle, of good geometric regularity and with a spread of about 50 points! Now, why would the control chart show an even state of control in rather narrow limits with such an actual distribution of values?

It was observed that the hourly production was 30 to 34 pieces. The cycle contained from 15 to 20 pieces. Two cycles equal approximately one hour's production. A comparison of Figures 2 and 3 shows that we were taking the samples at the bottom of the cycle where the values clustered to give the small $\bar{R}$ and an average close to zero

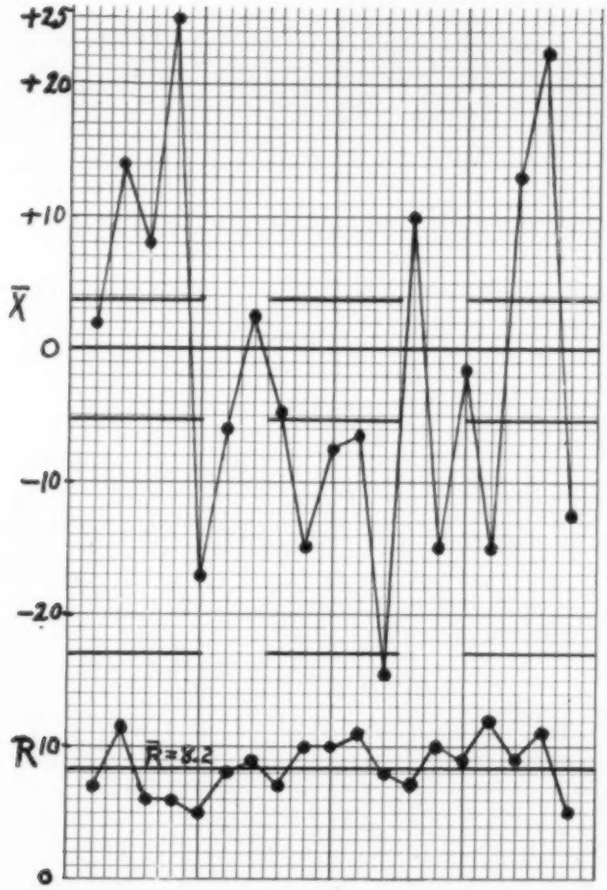


FIGURE 1 — CONTROL CHARTS ON FLYWHEEL OD— FIRST STAGE

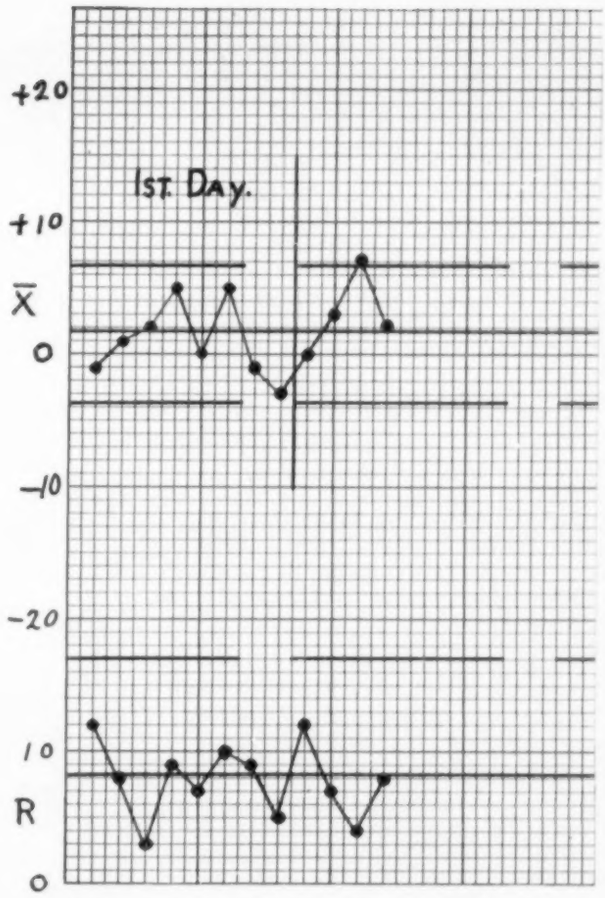


FIGURE 2 — CONTROL CHARTS ON FLYWHEEL OD — SECOND STAGE

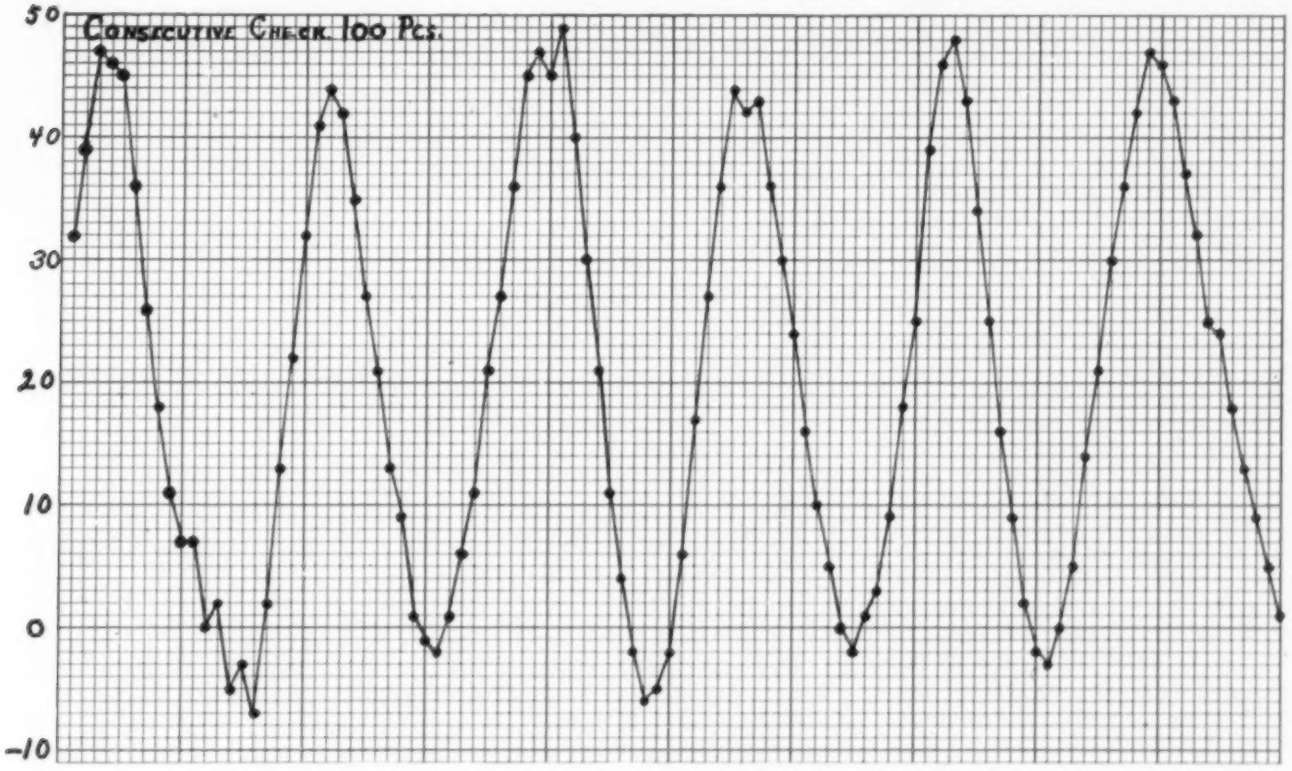


FIGURE 3 — INDIVIDUAL FLYWHEEL OD'S — 100 CONSECUTIVE PIECES

whereas the true average was approximately 20. For the short periods of time recorded we would stay at about the same place in the cycle with continuous production and a uniform time interval between samples.

By mounting an indicator on an overarm from the head stock housing we checked and charted the positioning of the tool block on 100 consecutive operational cycles and found a very similar pattern of variation existing. (See Figure 4)

The tool block is actuated by a mechanically driven cam. After reworking the cam mechanism we ran another variation pattern diagram of 100 readings on the tool block. (See Figure 5) The repair job instead of eliminating the cycle had merely increased its band or width from 15 to 26, and doubled the frequency.

Another more thorough rework of the cam mechanism resulted in a tool block variation pattern with no cycle present and very little variability from one piece to the next. However, there was still a very gradual trend in one direction due to tool pressure, as the tool gets dull and does not cut as freely. (See Figure 6) The 200 cycles checked were consecutive with the same tool.

It would be nice to end this story with a "They-lived-happily-ever-after" control chart showing all points in control and a record of good pieces produced. Unfortunately things did not happen quite this way. The operator, an oldtimer in the shop, who felt that his former method of tool setting was good enough, changed his role of victim and became the villain by his reluctance to set the tool with the aid of the chart and the gage, and our $\bar{X}$ chart still showed very bad control.

We therefore made a check of 200 consecutive pieces, almost an entire day's production. The check began early in the morning when the stock, machine and the tools were cold. As a result, the first hour's production was out of the control limits on the low side, but well within the engineering specifications. After reaching operating temperatures, all values then fell in the control limits and throughout the entire check not one piece was found out of engineering limits. (See Figure 7) It should be noted that in addition to the growth due to temperature, the trend shown in Figure 6 also plays a small part in the increase in size.

In presenting this article, no attempt is made or intended to discredit con-

FIGURE 4 — VARIATION IN TOOL BLOCK TRAVEL BEFORE CAM ADJUSTMENT

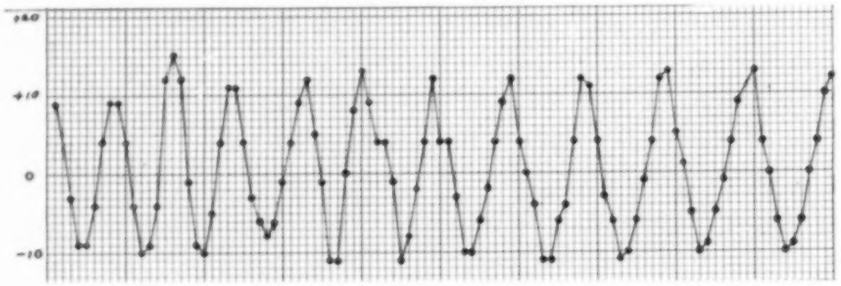


FIGURE 5 — VARIATION IN TOOL BLOCK TRAVEL AFTER FIRST CAM ADJUSTMENT

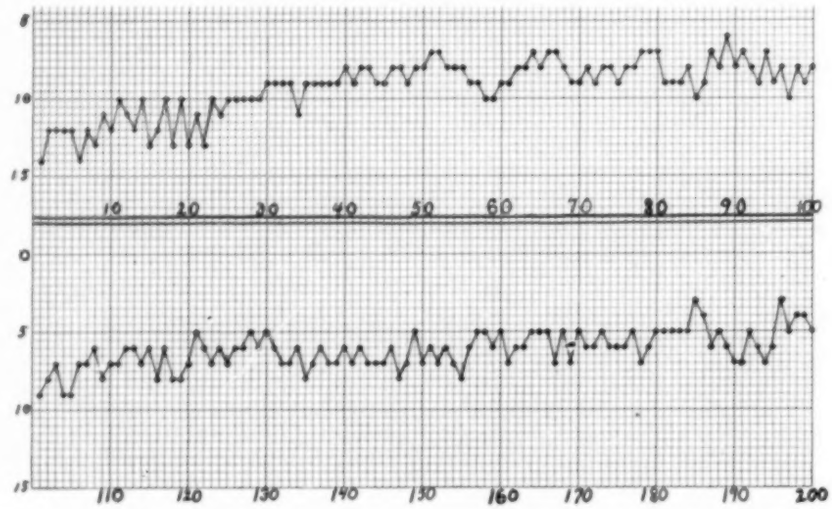


FIGURE 6 — TOOL BLOCK VARIATION AFTER SECOND CAM ADJUSTMENT

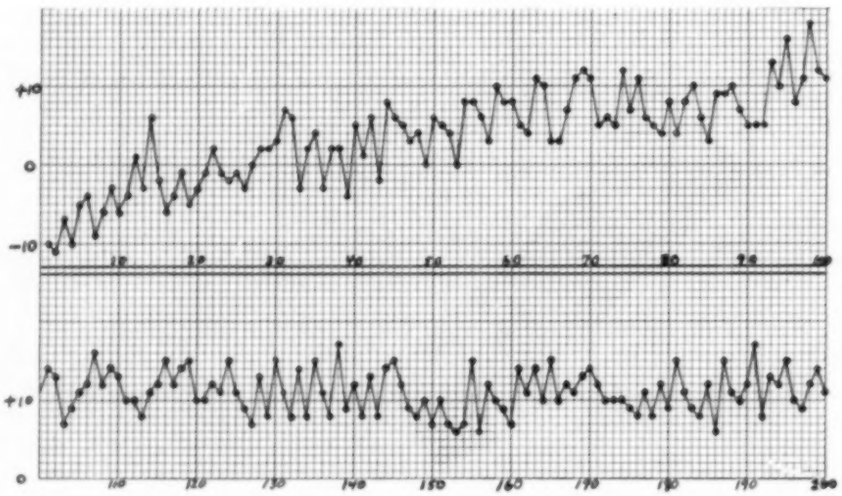


FIGURE 7 — FLYWHEEL OD'S — 200 CONSECUTIVE PIECES

trol charts for variables. We do believe that such a situation as described herein can exist under certain conditions and should be considered where the actual piece part results do not coincide with the chart.

Two primary lessons have been reemphasized for us in this experience. They are:

1. The value of a continuous chart of consecutive parts from an operation.
2. The desirability of deliberately staggering the time interval between samples to a greater extent than is usually considered necessary.

REPORT OF THE

Third Annual Convention American Society for Quality Control

AND THE

Third Annual New England Quality Control Conference

The Third Annual Convention of the American Society for Quality Control, held in conjunction with the Third New England Quality Control Conference at the Copley Plaza Hotel in Boston, May 5-6, maintained in every way the tradition for all-round excellence that has now become the accepted pattern for annual meetings of the Society. An exceptionally well-balanced program, built around the convention theme "Controlled Quality is Good Economy," provided discussions of both techniques and applications in a broad coverage of topics that challenged the attention of a wide range of interests.

The convention, with a total registration of close to 700, was marked by an unusually even distribution of attendance at all sessions. The session series on "Quality Control Engineering" drew a large number who were interested in the two-day practical course. The series "Management's Problems of Quality" proved to be a strong attraction for the many people who were there to get a fresh start on their problems from this point of view. Technically-minded quality control folks flocked in overflow numbers to hear the "Advanced Techniques" sessions and bring themselves more up to date in the field. Under the heading "Selected Topics of Special Interest" there was a well attended variety of sessions ranging from gaging and standards to education and training panels.

NOTICE

There are available as of May 31st about 400 copies of the booklet "Abstracts" containing condensations of 41 of the papers given on the program of the Third Annual ASQC Convention.

Copies may be ordered at $1.50 per copy, postpaid, from

Professor W. A. MacCrehan
New York University
New York 53, N. Y.

Make check payable to
Third Annual ASQC Convention.

Twenty-two companies played host to a steady flow of visitors interested in the equipment on display in the Convention Exhibits. Situated in this area also was a Book Booth, featuring a stock of publications of ASQC and most of the currently available books on Quality Control and related topics. Newest addition to this list was the booklet "Abstracts," containing condensations of 41 of the papers given on the convention program. A few extra copies of this booklet are still available, as indicated in the boxed notice accompanying this report.

Another outstanding contribution to the success of the Convention was the special slide film "Sightseeing Quality Control in New England." The picture was prepared especially for this convention and was shown along with the Johns-Manville film "Modern Quality Control."

Numerous Board and Committee meetings of the Society were held during the Convention. Attendance at these meetings was consistently good, and a number of important matters relative to the conduct of the affairs of the Society were discussed and voted on. Action taken at most of these meetings will be reported in the columns of the American Society News section of this magazine.

The Planning Committee of the New England Sections, the Associated Industries of Massachusetts, and the Copley Plaza Hotel are to be congratulated for the success of their joint efforts in carrying to completion a very full program of activity. Especially noteworthy was the excellent quality of the food and service provided guests of the convention by the Copley Plaza Hotel. All who were able to attend these meetings had

an opportunity to enjoy a stimulating program, to renew old friendships and make new ones, and to share an atmosphere of good fellowship and inspiration.

LUNCHEON SESSION—MAY 5th

The luncheon session on Thursday featured an address by Mr. Andrew B. Holmstrom, Vice-President of Norton Company, who spoke on "Quality Control in New England." Major W. W. Drummey, representing Governor Dever of Massachusetts, welcomed the visitors to New England.

In his talk, Mr. Holmstrom reviewed the history of the introduction of statistical quality control as an accepted technique in many of the leading industries in New England, and spoke in particular of its status and operations in his own company. In this connection he said, in part, "Quality Control is perhaps the most effective new tool that has been introduced into scientific management in the last 15 or 25 years. It has brought home to us the thought that you can't **wish** quality into a product; you have to **build** it in, for a product is no better **after** inspection than it was **before** inspection."

"After five years of experience with Statistical Quality Control, Norton Company Management is satisfied that it has made possible a better product; rejections, reworks and complaints have been reduced over 50% and the cost of inspection has been reduced. Our new five-acre plant is a grand success because its operation is based on inspection along the line, and Statistical Quality Control is a guiding factor. Quality Control methods will be the guiding force in Norton Company production until some better method has been discovered. We hope to learn how to use it better so that we can send even higher quality products to our customers throughout the United States who have always looked to us for fine workmanship."

"To those of you who are attending the Conference in order to become acquainted with Quality Control, we say that we firmly believe that it will help you as it has helped us not only to produce better quality but also to lower costs, speed up production, cut down waste, and improve personnel relations."

"To those of you who have already inaugurated Quality Control, may I compliment you and your management on your foresightedness. I believe that you will not only avoid possible difficulties in the demand-for-quality period ahead, but that you are in a position to take advantage of that market."

LUNCHEON SESSION—MAY 6th

Lt. Col. Edward Gluck, Deputy District Chief, New York Ordnance District, was the principal speaker at the luncheon session on Friday. He spoke on "Self Help by Industry on Inspection for Armed Services." In his talk he outlined many of the problems, and current thinking concerning their solution, in connection with the vitally important activity of planning for Industrial Mobilization. Highlights of his address were are follows:

"Industrial Mobilization today is so huge a problem, that it must be **decentralized to Industry** and each prospective contractor if the problem is ever to be solved. This fact has been recognized both by the Government and Industry."

"Time is the vital factor in Industrial Mobilization planning. Tooling up periods are lengthy. The speed of start and conduct of future emergency (atom-guided missiles, etc.) will not permit such time to be available. A way must be found to minimize the time for not only tooling-up production, but also, inspection-acceptance. Planning **now** may save time in an emergency, and with relative minor cost. As a practical matter, time itself may **not** be saved after the emergency begins, no matter **what** money is available."

"Industry must be alerted to the need for thinking in terms of tolerances, which are not only closer than those for normal products, but also much closer to those of the near future; preventive gauging (to save time and waste); and other modern gauging (to get better production and less inspection and inspector personnel). Modern gauging includes the use of more automatic gauging machines, and more gauges built into the production machine. It also means more education of production personnel, particularly machine operators, to make them more quality-minded. Finally, it means investigation of new devices such as air-gauging for surface finishes, electrolimit gauges, etc."

"Emergency causes overall scarcity in certain basic factors of production, such as Material, Machines, Manpower, and Money. Industry must be alerted to the need for aiding conservation of such elements as a result of its economical production and inspection,—both to contribute to success in the emergency, and to be prepared for the competition of the post emergency period. This is no idle statement. Time after time in making current surveys, one hears a prospective contractor refer to the fact that he learned the value of inspection in World War II and has continued it into the post war period."

"In the past it was standard practice and planning for the Armed Services to determine requirements, which were conveyed to Industry to enable it to plan. That is still the ideal. However, again, the size of the problem, the uncertainty of M-Day (whether fixed or creeping), the indefiniteness of items needed (whether the subject of present Research and Development or future unknowns) make it essential that Industry do some estimating on its own,—if it and the country is not to be caught short. On that basis, something can be done in a general way with regard to planning and being prepared concerning inspection,—so as to save **time."**

"Such 'something' would include setting up an adequate inspection control system, a gage laboratory, preparing for closer tolerances, preventive gaging, and such modern gagings. An ingredient of any modern system today appears to be Quality Control, with accompanying statistics and research so as to constitute a progressive, living thing. A contractor should expect to furnish what is required, close to 100% acceptable, and so as to minimize Government inspection, — conditioned by getting **started** right as to production (tooling, production, process and final inspection by contractor). This may mean not only more highly qualified personnel for inspection,—but probably less of them."

"Current Munitions Board Annex 47 procedure contemplates that each prospective contractor will have a CIPR (Corporate Industrial Preparedness Representative). It would be wise if he caused himself to be constituted a Chairman of a Company Committee, which would include an Inspection as well as a Production Representative, to insure advance planning, sound negotiation, and **starting** production (and inspection) right."

In summarizing his remarks, Colonel Gluck made the following points:

1. "The **importance** of Self Help by Industry on Inspection for the Armed Services in that present Industrial Mobilization requires (a) decentralization to and help by Industry,—in connection with which a Contractor's Manual would be very desirable; (b) time to

DR. WALTER A. SHEWHART RECEIVES CERTIFICATE OF HONORARY MEMBERSHIP IN ASQC

GEORGE D. EDWARDS RECEIVES CERTIFICATE OF HONORARY MEMBERSHIP IN ASQC

be saved now by planning; (c) modernization of industry's inspection, and (d) economy in event of emergency for the factors of production, especially manpower."

2. "Planning by Industry may be helpful, in that (a) requirements may be estimated as to general effect on Inspection, (b) inspection System should be provided for,—to include quality control, (c) planning system should be established, to include inspection coverage."

3. "Planning by Armed Services may have to be on the basis that (a) personnel will be lacking, (b) higher quality will be needed, (c) pre-audit of contractors may be required, (d) inspection will be organized separately to the extent possible."

"Though some of the foregoing may appear elementary, it is hoped you will constitute yourself ambassadors to industry to get it to **save time now,** with relatively minor cost in dollars, to get the essentials of an adequate inspection setup, with quality control, which it may not be able to get in emergency no matter how many dollars are available."

Also featured at the Friday luncheon was the presentation by Mr. George D. Edwards of a certificate of honorary membership in ASQC to Dr. Walter A. Shewhart. In making this presentation, Mr. Edwards spoke as follows:

"Two years ago, at our first Convention in Chicago, I had the honor to notify Dr. Shewhart of his election to the Highest Honor which the Society can bestow,—to Honorary Membership in the American Society for Quality Control. At that time, I promised in due course, to present him with suitable evi-

COLONEL LESLIE E. SIMON RECEIVES SHEWHART MEDAL AS THE SOCIETY'S FIRST MEDALIST

dence of that election. The Executive Committee in effect told me I had undertaken this pleasant task and that I should finish it. It has taken me a long time, but with Mr. Wareham's kind consent, I am now ready to complete it."

"It is my great pleasure to present to you, Dr. Shewhart, at this time this much delayed certificate of your election to the Society's highest grade of Membership. It honors you, but you have honored us more in accepting it."

Ralph E. Wareham, President of ASQC, concluded the events of the Friday Luncheon program by presenting a certificate of honorary membership to Mr. George D. Edwards, who was most genuinely surprised and pleased by this previously unannounced action of the Board of Directors of the Society. In making the presentation, Mr. Wareham fittingly endorsed the action of the Board in thus selecting Mr. Edwards as the Society's second Honorary Member.

CONVENTION BANQUET— MAY 5th

The Third Annual Convention Banquet of ASQC was held on Thursday evening, May 5th. Mr. Joseph P. Spang, Jr., President of both the Gillette Safety Razor Company and the Associated Industries of Massachusetts, gave an address on the subject "Quality is a Business Must." His talk is published in full elsewhere in this issue.

In addition to Mr. Spang's address, the program also featured presentation of the Shewhart Medal Award to Col. Leslie E. Simon. This occasion marked the first such award to be made under the provisions set up for it, and Col. Simon thus becomes the Society's first Medalist. In accepting the Award, Col. Simon delivered an acceptance address on the subject "The Advancing Frontier of Quality Control." His talk appears in full elsewhere in this issue.

Prior to conferring the Shewhart Medal Award, Ralph E. Wareham, President of ASQC, presented Dr. Walter A. Shewhart with the first medal struck from the die.

The Citation naming Colonel Simon as the 1949 Medalist was given by Dr. Shewhart. Following the Citation, Mr. Philip L. Alger, Chairman of the Shewhart Medal Committee, spoke briefly on "The Shewhart Medal—Its Origin and Purpose." His remarks were as follows:

"In June of 1947, the Directors of our Society voted to establish the Shewhart Medal for the recognition of individuals who have made 'suitably outstanding contributions to the cause of

quality control.' In September, the Medal Committee was appointed, and in the following July its plans were announced. Six months later, your generous response had brought the medal fund to the desired total of nearly $2,000. This has enabled us to pay all expenses for creating the medal, with a remaining balance of some $200, that will cover the cost of future medals for several years to come."

"The commmittee members believe that the young artist, Robert Weinman, whom we selected to execute the medal, has created a very distinguished work of art. The medal design in reverse portrays a micrometer emblazoned with a control chart, signifying the taming of rampant manufacturing variations by the new art of quality control. The obverse presents a striking likeness of Dr. Shewhart, including his glasses and the benign expression with which we are all pleasantly familiar."

"The real questions before us this evening, however, are: why should we have such a medal at all, and to whom should it be awarded?"

"We **elect** persons to office, so that they may perform governmental or political services for us—thoughts of our own benefit being uppermost when we vote."

"We **appoint** other persons to positions in industry or government, so they may perform necessary tasks — here again with thoughts of results beneficial to ourselves."

"The process of choosing a medalist is quite different."

"We **select** a medalist, to do him honor, with no thought whatever of any quid pro quo on his part. There is a real social benefit from this, however."

"This benetit accrues when the act of awarding the medal focuses the spotlight of public attention on the recipient, revealing in clear light the qualities that have won for him the esteem of his peers. In this way, the public obtains a glimpse of the values that make up a profession such as ours, and young men everywhere are inspired to emulate the ideals personified by the medalist."

"What are these qualities that lead us to so honor a man as to give him a medal? First of all, he must have intellectual ability, enabling him to clear away a little of the dark cloud of ignorance that always surrounds us. Second, he must have the generosity of spirit that leads him to so express and restate his pioneering ideas that other members of his profession may benefit from them. And finally, he must have that warmth of human feeling that marks the true educator, endearing him to his students or disciples, even those who learn from him only remotely."

"All of these qualities are eminently personified in our first medalist, Dr. Walter Shewhart. The members of your medal committee feel honored to have been the instruments of your appreciation for his generous and pioneering contributions to the new profession of quality control."

Book Review

SAMPLING INSPECTION—Principles, Procedures, and Tables for Single, Double, and Sequential Sampling in Acceptance Inspection and Quality Control Based on Percent Defective. Freeman, H. A.; Friedman, Milton; Mosteller, Frederick; and Wallis, W. Allen—Editors. The Statistical Research Group, Columbia University. McGraw-Hill Book Company, Inc., New York and London, 1948. xx and 395 pp. (3 plates). $5.25. Review by Harry G. Romig, New York, N. Y.

This book provides a compendium of results of certain wartime work on a general system of sampling inspection. It presents more than 350 sampling plans for use by industry in the inspection of products on an attributes basis, where units are classed as conforming or nonconforming with respect to certain selected engineering requirements. They are primarily acceptance-rejection plans, although the editors have extended their scope by describing how such plans may be related to standard control charts. Chapters 6 (pp. 55-68) and 13 (pp. 135-136) discuss this feature, but the limitations imposed by tying in the control features with these acceptance-rejection plans, for which Operating-Characteristic (OC) curves are available, would appear to weaken the flexibility of the control chart system, while the additional information provided by the OC curves does not add sufficient advantages to influence one to substitute these plans for the usual standardized procedures.

The editors have had the first four parts written around Part V, which presents four tables covering a system of sampling plans. Table 2 is presented on the three plates:

2a—Single-Sampling Plans,
2b—Double-Sampling Plans, and
2c—Sequential-Sampling Plans.

The other three tables plus a supplementary table provide material necessary for use in connection with the plans, such as Sample Size Letter and AOQL (Average Outgoing Quality Limit) values. Table 4 (pp. 221-379) gives Operating-Characteristic curves for the sampling plans, in three colors.

The plan of the entire work is to make each part practically self-contained, so that in practical applications many of the parts need not be considered. This arrangement results in considerable duplication in certain parts for some features. The editors have done a splendid piece of work in combining in one volume and co-ordinating the work of so many individuals. They have carefully given credit at all times to the various sources from which they obtained materials used and have indicated the individuals or groups that developed the various parts of the book. The table of contents, list of figures and tables, glossary of terms, and index are very complete and make the book an excellent reference work. The text is remarkably free from errors, a boon to the reader.

This work presents one system very completely. The suggested forms of Chapter 12 (pp. 129-133) and the procedure for reviewing past results of Chapter 11 (pp. 115-127) relate to the system described, and may need to be modified for application to a different system. Much of the descriptive material is sufficiently general so that it pro-

vides basic principles of a large number of different acceptance-rejection sampling systems. The proposed system has a wide field of application, but its limitations should be clearly understood.

The fundamental principles or basic factors underlying any system of sampling plans are limited since, if certain variable numerical factors are fixed as the bases of the system, the numerical values of other factors depend upon the fundamental relations and cannot be controlled, although readily computed.

A choice of the factors to control must be made from those factors available that are associated with a system of sampling plans, such as the Acceptable Quality Level factor with a series of fixed single AQL values for sampling plans covering a series of lot sizes or ranges of lot sizes, or even a range of AQL values listed in place of a single AQL value. Among the many basic factors available may be mentioned the AOQL concept, the requirement that the same sample sizes be used for the same lot size for a series of quality levels, a fixed Consumer's Risk for some stated level of quality for each sampling plan in a series, and minimum average amount of inspection per lot for process average quality, including or not including the additional inspection due to the detailed inspection of the balance of the units in rejected lots.

The editors state on page vi: "As Part IV brings out, the tables and procedures in this book are in large measure adapted from or based on Army Ordnance tables and procedures." Again, on page 141 is stated: "The excellent tables and procedures of the Army Ordnance Department* are the immediate precursor of the tables in this book, which, while it differs in many respects from the Ordnance tables and procedures, adopts the same fundamental approaches." The editors discuss the Ordnance Tables and continue: "In general, they are well constructed and incorporate the latest developments in single and double-sampling plans."

As mentioned above, these inspection plans for single- and double-sampling are based on the Ordnance Sampling Plans modified to meet the requirement that the Probability of Acceptance, P_a be made equal to 0.95 for the designated AQL (Acceptable Quality Level) value. The sequential-sampling plans, as stated in a footnote on page 155, are based on two concepts or factors:

1. A Probability of Acceptance (P_a) value of 0.95 for a level of quality, termed the Acceptable Quality Level (AQL); and
2. A Probability of Acceptance (P_a) value of 0.10 for a quality level poorer than the AQL, termed the Lot Tolerance Percent Defective (LTPD).

Using the values of AQL and LTPD so defined that occur on the OC curves for similar single- and double-sampling plans, a sequential-sampling plan is obtained whose OC curve best matches the corresponding OC curves for single- and double-sampling. The sampling tables in the text are essentially the Ordnance Sampling Plans plus a matching Sequential-Sampling Plan. Some modifications have been introduced based on added assumptions and a different method of approach, which the text strives to justify as each change is introduced.

The first entry in the Glossary (p. 383) defines Acceptable Quality Level, AQL, differently than given elsewhere as explained by the editors in the footnote on page 23: "In some other collections of tables, including the one in the publication cited in the previous footnote (Ord-M608-8), the term 'acceptable-quality-level' has a slightly different meaning." The Glossary defines AQL as: "Percentage of defective items in an inspection lot such that the sampling plan will result in the acceptance of 95 percent of submitted inspection lots containing that percentage of defective items." This definition makes the AQL a property of the inspection plan, whereas the original definition (Army Ordnance) is: "The Acceptable Quality Level (AQL) is the maximum percent defective which can be considered satisfactory as a process average; that is, it is the poorest quality which a producer can be permitted continually to present for acceptance."

The editors defend their choice by stating: "First, it makes the AQL a technical property of the sampling.-----The second feature of the definition of AQL that requires discussion is the choice of 95 as a percentage representing 'close to 100.' This choice is essentially arbitrary."

Practically, due to discreteness of sample sizes and acceptance numbers, the probabilities of 0.95 and 0.10 usually are not exactly obtained. The editors claim that the basis of all the plans is the AQL value assigned. However, since these sampling tables list the AQL values in range form, e. g. AQL class 0.65-1.2 (percent defective) on page 256, the p value to which the probability 0.95 applies is neither definite nor clear. Hence, as stated on page 150, it was necessary to modify the desired procedure, 0.92 being set arbitrarily as the minimum P_a value for the maximum value of AQL in each AQL class. Only a few plans have P_a values less than 0.92. A fixed P_a value, the basis of the new definition of AQL appears to have been lost by this compromise.

In determining probability values for the Probability of Acceptance curves, termed Operating Characteristic curves or OC curves, the basis used in this work is "Lot Quality," not "Product Quality"; hence, for a given plan a different curve should be computed for each different lot size. This is not done as the Poisson exponential probabilities are used for the larger n values, and in cases where the n values are less than or equal to 50, the binomial distribution probabilities available in Pearson's Tables of the Incomplete Beta Function are used. For consistency in this system, binomial values should have been determined at least for all n values where p exceeds 0.10.

The editors, however, do not wish to consider lots of varying quality, but only lots of fixed quality, and explain in the text and a footnote (p. 19): "When inspection lots are large compared with the sample, variation in inspection lot size has little effect on the percentage of lots accepted . . . . For this reason, the OC curve of a sampling plan is often given without specifying the inspection lot size. Such OC curves are computed on the assumption that the inspection lot is large compared with the sample and are, therefore, only approximate when this assumption is not valid."

The use of "Lot Quality" rather than "Product Quality" assumes that all lots in a series of lots contain exactly pN defectives. Even the editors consider this assumption unrealistic, stating in a footnote (p. 25): "This paradox depends on the highly unrealistic assumption that all inspection lots submitted contain exactly the same percentage of defective items." On page 184 they continue: "This book is not entirely consistent on the interpretation placed on the OC Curves. In most of the textual discussion interpretation (a) is adopted."

* Army Service Forces, Ordnance Department, Industrial Service: **Ordnance Inspection Handbook on Standard Inspection Procedures, Quality Control,** Ord-M608-8.

(p. 183: "(a) The percentage of defective items can be considered as applying to each inspection lot separately. (b) The percentage of defective items can be considered as applying to the process yielding a particular inspection lot, and each inspection lot can be considered as itself a sample from a hypothetical infinite population of items that might be produced if the process remained unchanged.") "On the other hand, the OC curves are, in fact, computed under interpretation (b) in order to avoid the necessity of giving them as functions of inspection lot size."

The OC Curves for Sequential-Sampling Plans are recognized to be only approximations as the task of computing exact Probability of Acceptance values for the Multiple-Sampling Plans in the text with large Acceptance and Rejection numbers is a prodigious task. However, the results given by the approximations appear, in general, to be good enough for practical usage. The methods used in the computations are presented quite completely and forms are given that greatly simplify the work.

In addition to all these approximations for use in connection with single-, double-, and sequential-sampling plans, which introduce unavoidable errors, the printing of the OC Curves in three colors on a black grid, although perhaps easier for the reader to follow unnecessarily adds rather sizable errors. On page x, the Accuracy of the Charts is discussed with respect to mathematical approximations used in their preparation, number of points plotted per curve, and limitations on the accuracy of four-color printing. For the latter, the editors state (p. x): "When the percentage of submitted lots accepted is in the neighborhood of 90, the error (deviation of the chart reading from the computed value) has a standard deviation of about 1.1; in the neighborhood of 50 the standard deviation is about 1.5; and in the neighborhood of 10 the standard deviation is about 1.0."

Little account is given to the methods of computation for AOQ and AOQL values. The values determined are generally only rough approximations, as the lot size is treated as being infinite and pL_p is used as the value for AOQ, where L_p is the Probability of Acceptance. Taking account of the lot size is one of the more important factors in developing and using the AOQL concept and here it is ignored to all intents. Since values of AOQL are generally given in ranges this criticism may be too severe.

As noted by the editors, the notion of Major and Minor, as well as the use of three grades of inspection—Normal, Tightened, and Reduced—are taken from the Army Ordnance procedure. Unfortunately, the Reduced Inspection Plan in this book does not include some of the more valuable features of the Army Ordnance Tables and Procedures, wherein, for product that has qualified for Reduced Inspection, cumulative inspection results from five consecutive samples, including the current sample, in addition to the results from the current sample, are checked against their appropriate criteria. The editors merely slip back two inspection levels, Level V becoming Level III, etc. Level I has no provision for Reduced Inspection.

The editors point out on p. 142: "Sequential sampling had not been developed when the Army Ordnance tables were constructed." However, in a footnote in the Preface, reference is made to Professor W. Bartky's "Multiple Sampling with Constant Probability," **Annals of Mathematical Statistics,** December, 1943. As a matter of historic interest, Multiple Sampling plans developed by Bartky as early as 1927 in unpublished memoranda for use in the Bell System had been tried out for a number of years, but had found less practical favor than double sampling although applied to continuous production, similar to what the editors on page 87 term the "moving inspection lot." The sequential plans in the table were developed on the basis of Professor A. Wald's well-known work "Sequential Tests of Statistical Hypotheses" and his more recent book on the same subject. The plans are really multiple-sampling plans as they consist of a series of samples, never more than 9 and all of equal size in most cases for ease of application. Actually, the distribution of plans is as follows:

No. of Samples	Freq. of Occurrence
100%	2
1	39
2	0
3	2
4	0
5	12
6	8
7	88
8	37
9	18
Total	206

This table includes a count for every AQL class and sample-size letter. As a result of this method of count some sampling plans will be counted several times since they are applied to more than one sample-size letter. For example, for the AQL class 0.024-0.035, the sampling plan for sample-size letter J is also designated for sample-size letters C, D, E, F, G, H, and I, and is counted 8 times.

In comparing the three types of inspection, single, double ,and sequential, with respect to the average number of items inspected per inspection lot, termed the Average Sample Number (ASN), the editors present first an example (p. 31, Fig. 3.7) for the AQL class 3.2-4.4 percent defective, which they term "high-quality inspection lots" since the percent defective is large or "high." In this example, for Single Sampling the Acceptance number $c=14$, and for Double Sampling the Acceptance Numbers are c_1, $c_2=9$, 23. This example and three other examples are given in Fig. 9.2 (p. 95). The Acceptance Numbers for Single and Double Sampling for these three additional examples are: (1) S. S.: $c=2$, D.S.: c_1, $c_2=1$, 2; (2) S.S.: $c=1$, D.S.: c_1, $c_2=0$, 2; (3) Given above; (4) S.S.: $c=14$, D.S.: c_1, $c_2=8$, 25. Based on the ASN values for these four examples the editors state (p. 34): "For high-quality product double sampling frequently requires something like 1/4 to 1/3 less inspection than single sampling, and sequential sampling requires something like 1/3 to 1/2 less inspection than single sampling." In the summary table on page 35 it is indicated that single sampling requires the "Most" average number of items inspected per inspection lot, double sampling requires "Less," and sequential sampling requires the "Least."

The above generalization holds fairly well when the percent defective in submitted product is large and the acceptance numbers for both single and double sampling are, relatively speaking, large. However, for the better-quality products where the quality levels are small, in many cases close to zero, say of the order of 0.1%, and in many other fields of application, the majority of the sampling plans are in the area where acceptance numbers are small, say $c=0$, 1, and 2 for single sampling, and, correspondingly, c_1, $c_2=0$, 1; 0, 2; 0, 3; etc. for comparable double-sampling plans. In such cases there is little difference between the ASN values for the three types of inspection.

In many instances in the range of quality levels of interest, the single-sampling or double-sampling plans may have smaller ASN values than the corresponding sequential-sampling plans. This is particularly true for the single-sampling plan with $c = 0$, and is recognized in this book by designating such a single-sampling plan also for both double- and sequential-sampling plans for the AQL class and sample-size letter under consideration. When a double-sampling plan has c_1, $c_2 = 0, 1$, the corresponding sequential-sampling plan is so set up that the first sample, required generally to be inspected completely for all three types of plans (p. 33), is considerably smaller than that for double sampling although a larger sample must be taken in order to accept with an acceptance number of zero (0), i. e. the larger sample consists of the first, second, etc. samples. Inspection thus can be curtailed sooner in the sequential-sampling plan when too many defectives occur early in the sample or samples from the inspection lot. This usually will result in smaller ASN values for sequential than for double sampling. For the majority of the sets of sampling plans in this book, where matching sequential-sampling plans are given when the double-sampling plans' acceptance numbers are c_1, $c_2 = 0, 1$, the OC curve for sequential sampling is not so strict as that for double sampling and affords slightly less protection against the acceptance of defective product.

The text's discussion of the relative magnitudes of ASN values for the three types of inspection is fairly complete, but neglects the important sampling area discussed above. The many considerations enumerated in the book should be studied before selecting the type of inspection that best fits any set of conditions.

Where the sampling plans are to apply to Process Inspection, or the basis of protection is the AOQL designated for Average-Quality protection, then the Average Amount of Inspection per Lot, I, for each type or system should also include the amount of inspection performed on the balance of rejected lots. The difference between the various I values for different systems will not be as great as between the ASN values mentioned above. The text does not discuss this point.

The admirable points of the book are self-evident and have not been stressed. The text discusses many other valuable items. How should samples be selected? The different techniques that apply to a "Stationary Inspection Lot" in contrast with a "Moving Inspection Lot" are developed and described. There is a wealth of material in the book and it should be carefully studied by those in the field of production and quality control. The editors are to be commended on doing a difficult task well and providing a system of sampling plans which have wide fields of application.

AMERICAN SOCIETY NEWS

GEORGE D. EDWARDS ELECTED HONORARY MEMBER

By unanimous vote, the Board of Directors has elected Mr. George D. Edwards an Honorary Member of the Society. This action was taken on a petition received from thirty-two members of the Society, requesting that Honorary Membership be granted in view of Mr. Edwards' "acknowledged eminent service to quality control during his more than two years as the first President of the American Society for Quality Control."

BOARD OF DIRECTORS MEETING HELD

The Board of Directors held a meeting during the Boston Convention on Thursday afternoon, May 5, just preceding the Annual Society Dinner. All of the Officers, 20 Directors, and one Alternate Director were present.

The Executive Secretary reported a total Society membership of 2601, a 24% increase from the 2092 members at June 30, 1948. In this report, it was noted that 74% of members had renewed this year and that new memberships had accounted for the balance of present membership.

The Treasurer reported receipts of $19,786.13 during the first 10 months of this Society year and disbursements of $18,173.90 during the same period. The balance of general funds on hand as of May 1, 1949, was $5,975.05. All of the figures reported above are exclusive of the Shewhart Medal Fund and the Brumbaugh Award Fund which are maintained in separate Society accounts.

The Directors voted to establish the official Society headquarters in the Society office in the Grand Central Terminal Building, New York, for the next Society year.

Plans were discussed for the renewal of memberships for the 1949-50 Society year and for cooperation between the national office and Section officers in billing membership dues.

There was considerable discussion of the matter of accepting Society memberships from outside the United States and Canada. It was finally voted that such memberships would be accepted only after individual approval by the Board of Directors or the Executive Committee acting for the Board. Renewals of present foreign memberships will be submitted to the Board before further dues are accepted.

The report of the Brumbaugh Award Committee was received and reviewed, and the applications of two new Sections were accepted as outlined below.

BRUMBAUGH AWARD COMMITTEE

At the Board of Directors meeting in Boston, the Brumbaugh Award Committee reported its recommendations as to future procedure for the Award. This report was unanimously accepted by the Board, and steps were taken to make the recommendations effective.

In reporting these recommendations, the Brumbaugh Award Committee completed its initial responsibilities. The Board of Directors has reappointed the members of the Committee to serve as the Award Committee for varying terms as follows:

One Year Term: Claudius S. Barrett
Parker D. Deans

Two Year Term:	Joseph J. Ferri Wyatt H. Lewis
Three Year Term:	H. Harold Sheaffer Charles R. Scott
Four Year Term:	Mason E. Wescott Halsey H. Kent, Chairman

All terms listed above begin on July 1, 1949.

The terms of two members of the Committee will thus expire each year. Appointments to the Committee in subsequent years will be for four-year terms.

PLANS FOR THE BRUMBAUGH AWARD

As recommended by the Brumbaugh Award Committee, the following plan has been approved by the Board of Directors for making the first Brumbaugh Award:

1. The annual cash award will be $50 to the author of that paper published in INDUSTRIAL QUALITY CONTROL and judged to have made the greatest contribution to the development of industrial applications of quality control.
2. The Brumbaugh Award Committee will make its selection for the first Award from the papers published in INDUSTRIAL QUALITY CONTROL during the five year period July 1944 to June 1949. Thereafter, Awards will be made from among articles published during a Society year.
3. Any member of the Society, or groups of members, may recommend a paper for consideration by the Brumbaugh Award Committee. Such recommendations should be submitted in writing and sent to the Executive Secretary of the Society. Recommendations for the first Award must reach the Executive Secretary on or before November 1, 1949.
4. The Brumbaugh Award Committee will meet shortly after November 1 and will make its decision as to the winner before January 1, 1950.
5. The first Award will be presented at the Society's Convention in Milwaukee, June, 1950.

Members of the Society are urged to submit recommendations without delay.

NEW SECTIONS RECOGNIZED

At its meeting in Boston on May 5, the Board of Directors had the pleasure of approving the applications of two new quality control groups as Sections of the American Society for Quality Control.

The Muncie Section was approved as the 34th Section of the Society. Its headquarters will be in Muncie, Indiana; the Section will be part of the Midwest Region.

The New Hampshire Section was approved as the 35th Section of the Society. Its headquarters will be at Laconia, New Hampshire; the Section will be part of the New England Region.

The Society warmly welcomes both of these new Sections, located as they are in important industrial areas.

ANNUAL MEETING 1949

In accordance with the decision of the Board of Directors, under the provision of Section 60 a. of the Constitution, the Annual Meeting of the Society will be held in Room 502 at the Engineering Societies Building, 33 West 39th Street, New York, N. Y. at 8 p. m. on Friday evening, 17 June 1949.

Principal business to come before the meeting will be:

1. Presentation and Acceptance of Annual Reports of the Board of Directors, the Executive Secretary, and the Treasurer;
2. Election of officers for the fiscal year 1949-50;
3. Any other matters which properly may be brought before the meeting.

As provided in Section 60a. of the Constitution, formal notice of the Annual Meeting has been mailed by the Executive Secretary to every corporate member of the Society. This notice has been accompanied by an Official Ballot for the election of officers and envelopes for the return of this Ballot as required by Sections 56 and 57 of the Constitution.

YEARBOOK 1948-49

The 1948-49 Yearbook of the Society is now in the hands of the printers and should reach members soon after this issue of the magazine. The closing date of 15 April 1949 was set for membership records in the Yearbook. All new memberships and renewals in the hands of the Executive Secretary on that date will appear in the Yearbook.

In accordance with Section 16. of the Constitution, the names of all members delinquent in their dues as of 1 April 1949 have been dropped from membership and none of these will be included in the forthcoming Yearbook.

The Yearbook includes complete information on Society organization and committees; it lists Society members alphabetically along with their Section affiliation; it includes a catalogue of Section officers and their addresses.

MEMBERS-IN-TRAINING

By mail ballot, the Board of Directors has adopted the By-Laws proposed by the Committee on Constitution and By-Laws covering Members-In-Training and student "Branches" of the Society. The provisions cover enrollment of individual Members-in-Training as well as affiliation of student organizations at educational institutions.

Principal provisions of the By-Laws are as follows:

1. Any person under 21 years of age and interested in quality control work may be enrolled as a Member-in-Training and may be re-enrolled until he reaches age 22.
2. Any bona fide full-time or cooperative student, graduate or undergraduate, in a university or technical school of recognized standing, may be enrolled as a Member-In-Training and may be re-enrolled for subsequent years while he is a student. However, no student may be re-enrolled after age 26 or after 6 years as a Member-In-Training.
3. Any bona fide trainee in industry, regardless of age, may be enrolled as a Member-In-Training. He may be re-enrolled only for the following year.
4. Members-In-Training will receive INDUSTRIAL QUALITY CONTROL while enrolled and will pay dues of $3 for each fiscal year.
5. In any university or technical school from which Members-In-Training are enrolled, any member of the faculty who is a corporate member of the Society may, upon approval of the Executive Committee, organize such Members-In-Training into a student "Branch" of the Society. The President of ASQC will appoint a corporate member of the Society to act as Counselor of the student Branch.
6. An established student engineering society in a university or technical school of recognized standing may, upon application of its officers and of a corporate member of the Society connected with the university or technical school, and with the approval of the Executive Committee, become associated with the Society. A society so associated may also be associated jointly with other national engineering societies, in which case

it will be known as a "Joint Branch."

Adoption of these By-Laws brings our Society policy in accord with that of other national engineering societies.

EXECUTIVE COMMITTEE MEETS

A successful meeting of the Executive Committee was held on May 6 and 7 at Boston following the Society's Third Annual Convention. All but one of the twelve members of the Executive Committee were present or were represented by alternates.

Reports and recommendations were received from the Special Committees on Society Information (S. C. Bates, Chairman), Membership Application Blanks (S. C. Amren, Chairman), and Membership Renewal Procedure (Dorian Shainin, Chairman). After considerable discussion, it was voted to modify the Society Information Folder and Application Blank in accord with certain of these recommendations and to establish a membership renewal procedure along the lines recommended.

The Executive Committee received reports from the Examining Committee, the Brumbaugh Award Committee, the Shewhart Medal Committee, the Standards Committee, the Advertising Committee, the Committee on Membership, and the Committee on Publicity and Public Relations.

The Chairman of the Editorial Board reported on plans for adding editorial departments to the magazine so as to extend its scope and usefulness to members. A program for joint cooperation between the Editorial Board and the Advertising Committee was approved.

There was considerable discussion of institutional subscriptions to INDUSTRIAL QUALITY CONTROL and purchases of back issues. Because of the extra handling and mailing costs involved, it was decided to increase the price of current magazine subscriptions to $6.00 per year and increase back issues to $8.00 per volume.

Plans for the 1950 Convention in Milwaukee, the 1951 Convention in Cleveland, and the 1952 Convention in Syracuse were discussed and approved.

Arrangements were made for the Annual Meeting and for the audit of Society books at the close of the fiscal year.

POSITIONS WANTED

College graduate with two years experience as inspection standards engineer for well-known manufacturing firm desires position in quality control work. Age 28; Senior Member ASQC. Reply to 5F1, American Society for Quality Control, 22 East 40 Street, New York 16, N. Y.

January graduate with majors in mathematics and mathematics of statistics desires position in quality control work. Member American Society for Quality Control and American Statistical Association. Reply to 5F2, American Society for Quality Control, 22 East 40 Street, New York 16, N. Y.

NOTICE

The Post Office Department does not forward IQC to a forwarding address. The magazine is delivered to the address on file with the Executive Secretary. **If you make a change of address and expect to get your copy of IQC, see that prompt notice of the new address is sent to**

Simon Collier
Executive Secretary, ASQC
22 East 40th Street
New York 16, N. Y.

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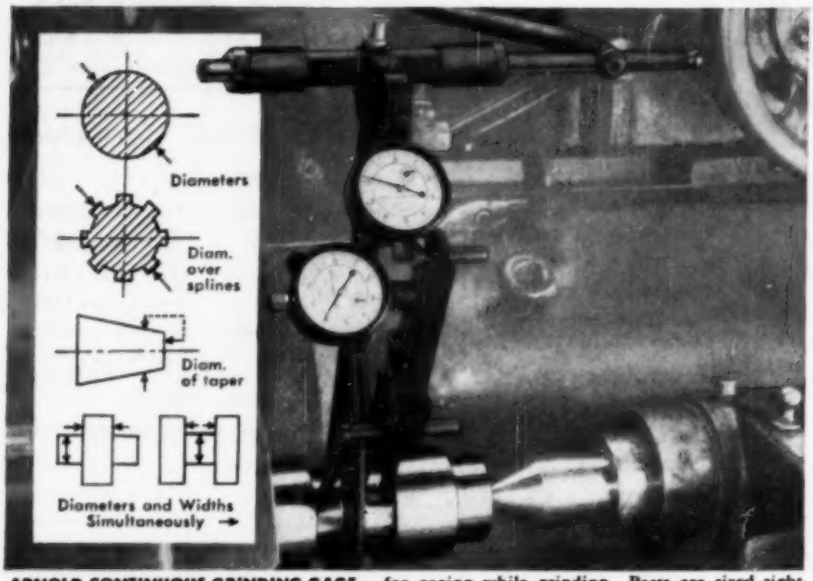

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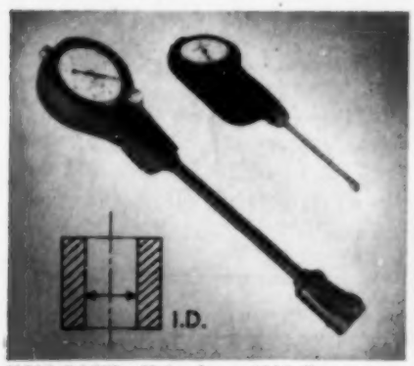

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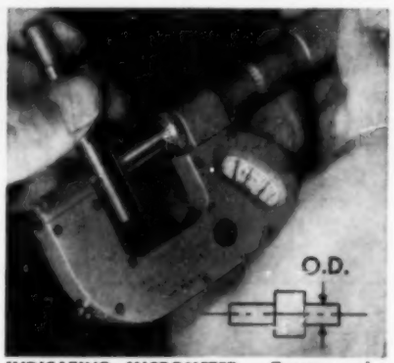

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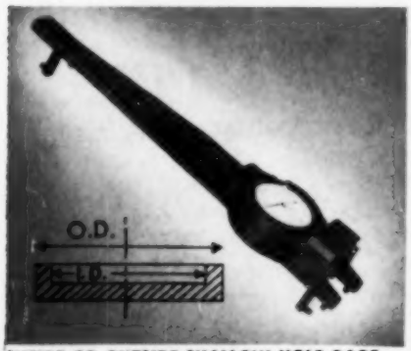

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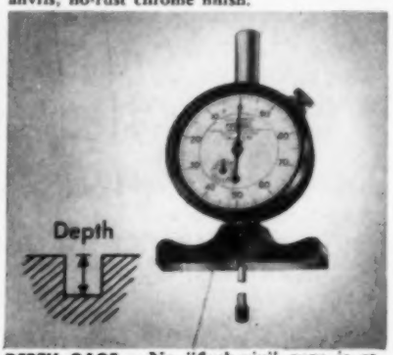

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